Michigan Department of Transportation

PAVEMENT DESIGN AND SELECTION MANUAL

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EXECUTIVE SUMMARY

The Michigan Department of Transportation (MDOT) has used various formal and informal pavement selection procedures throughout history. The approach, since 1985, uses the Life Cycle Cost Analysis (LCCA) method to compare costs of the pavement selection alternates. Pavement design of the alternates is performed using the AASHTO design method.

Life Cycle Cost Analysis is an objective, nationally recognized method used to quantify the cost effectiveness of various investment alternatives. Federal agencies have used this method for many years to determine long term capital investment strategies. The federal government, including the Federal Highway Administration (FHWA), recommends that all transportation agencies use a LCCA approach when evaluating various investment alternatives.

The most recent federal transportation act termed "The 1998 Transportation Equity Act for the 21st Century (TEA-21)" does not require that LCCA be used to make investment decisions on the National Highway System. However, the United States Congress has required that the Secretary of Transportation develop procedures and recommend that transportation agencies use LCCA when making investment decisions on the National Highway System.

State legislation was also enacted in 1997 regarding pavement selection and Life Cycle Cost Analysis. The legislation, PA 79, states that "the department shall develop and implement a life cycle cost analysis for each project for which total pavement costs exceed one million dollars funded in whole, or in part, with state funds. The department shall design and award paving projects utilizing material having the lowest life cycle costs." The legislation also states "life cycle costs shall also compare equivalent designs and shall be based upon Michigan's actual historic project maintenance, repair and resurfacing schedules and costs and shall include estimates of user costs throughout the entire pavement life."

MDOT's pavement selection policy requires that an LCCA be performed on all projects with paving costs greater than one million dollars. The department uses the Equivalent Uniform Annual Cost (EUAC) method to calculate a life cycle cost on a per annum basis. Inputs to a life cycle cost analysis include both initial costs and maintenance costs.

Initial Costs (Agency and User)
Initial agency costs may include pavement, shoulders, joints, subbase, base, underdrains, and traffic control. Only work items with costs that vary between alternates will be considered. Initial user costs are based on daily and hourly traffic volumes, possible detour routes, capacity, and construction work days. Work item unit prices are determined using the department's bid estimating system.

Maintaining traffic schemes are developed by the Region during project scoping and must be approved by the Region Engineer. The process requires that the Regions submit a memo outlining the maintaining traffic/stage construction scheme that will be used to construct the project. This information is required to calculate user costs and maintaining traffic costs for the various alternatives being considered in the analysis.

The submitted maintaining traffic scheme is based on what the Region determines will be the actual maintaining traffic plan when the project is eventually constructed. A memo, signed by the Region Engineer, should be addressed to the Pavement Engineer, Pavement Management Unit stating the desired maintaining traffic scheme with any necessary justification.

Pavement Preservation Strategies (*Future Agency and Future User Costs)*
Maintenance costs are determined from MDOT's actual historic maintenance data when available. The costs are retrieved from various maintenance sources both in Lansing and the Region offices. Historic maintenance data is also used, when available, to determine the pavement condition when the department typically takes preventive maintenance action on a particular fix type.

User costs for maintenance activities are determined by using tabulated values agreed upon with industry. Life extension values for any maintenance activities are determined using historical pavement condition data from the MDOT Pavement Management System when available. Initial fix life values are also determined from pavement performance data from the MDOT Pavement Management System.

All of this information is used to develop preservation strategies for specific rehabilitation or reconstruction fixes. These strategies (maintenance schedules) reflect the overall maintenance approach that has been used network-wide for a specific fix based on historical records.

CHAPTER 1. INTRODUCTION

MDOT is responsible for managing both the National Highway System and the State Trunkline system. As of 2003, these roadway networks total 9,721.7 route-miles which equate to approximately 28,000 lane-miles of roadway.

Many approaches can be employed to manage the condition of the highway system. These varying approaches can affect both project level and network level decision making. MDOT has identified long term pavement condition goals and has developed pavement management strategies that will achieve these long term condition goals.

These network-level pavement management strategies are reliant on cost-effective decision making at the project level. In other words, cost-effective selection of pavement fixes, for each project, can have a significant impact on the cost effectiveness of a network-wide pavement strategy.

MDOT has recognized this relationship and has developed a pavement selection process in cooperation with the asphalt and concrete paving industries. The approach uses life cycle cost analysis and MDOT's Pavement Management System as the basis for determining pavement selection on specific projects.

Subsequent chapters will explain the MDOT pavement design process and the procedures used to determine pavement selection.

CHAPTER 2. BACKGROUND

The Michigan Department of Transportation (MDOT) has used various formal and informal pavement selection procedures throughout history. The most recent procedure was developed in the 1980's and early 1990's and was documented in two publications, "Recommended Method of Pavement Selection - Life Cycle Costing of New and Reconstructed Pavements" and "Recommended Method of Pavement Selection - Life Cycle Costing of Rehabilitated Pavements".

A revised procedure was developed in 1998 and 1999 to meet new federal and state legislative requirements. The most recent federal transportation act termed "The 1998 Transportation Equity Act for the 21st Century (TEA-21)" does not require that LCCA be used to make investment decisions on the National Highway System. However, the United States Congress has required that the Secretary of Transportation develop procedures and recommend that transportation agencies use LCCA when making investment decisions on the National Highway System.

State legislation was also enacted in 1997 regarding pavement selection and Life Cycle Cost Analysis. The legislation, PA 79, states that "the department shall develop and implement a life cycle cost analysis for each project for which total pavement costs exceed one million dollars funded in whole, or in part, with state funds. The department shall design and award paving projects utilizing material having the lowest life cycle costs." The legislation also states "life cycle costs shall also compare equivalent designs and shall be based upon Michigan's actual historic project maintenance, repair and resurfacing schedules and costs and shall include estimates of user costs throughout the entire pavement life."

MDOT's new pavement selection policy requires that an LCCA be performed on all projects with paving costs greater than one million dollars. The department uses the Equivalent Uniform Annual Cost (EUAC) method to calculate a life cycle cost on a per annum basis. Inputs to a life cycle cost analysis include both initial costs and maintenance costs. Costs include both agency costs and user costs. The costs and maintenance schedules are based on actual cost and pavement performance data.

CHAPTER 3. PAVEMENT DESIGN

An effective pavement design is highly dependent upon performing an adequate investigation of the existing pavement structure. The investigation should include reviewing as-built plans, reviewing and analyzing existing pavement distress condition, determining causes of pavement surface distresses, evaluating pavement ride quality, reviewing pavement remaining service life and conducting both a drainage evaluation and subgrade evaluation. A drainage evaluation can be conducted by a visual inspection along with a soil boring investigation. A subgrade evaluation can be conducted by collecting soil boring information along with pavement deflection testing. Pavement deflection data can be analyzed to determine subgrade soil strength expressed in terms of Resilient Modulus.

A comprehensive investigation of the pavement structure will ensure that the Engineer selects the proper reconstruction or rehabilitation fix. The information obtained from the investigation also will aid the designer in selecting the appropriate input values for the pavement design.

MDOT uses the pavement design methodology recommended by the American Association of State Highway and Transportation Officials (AASHTO). The 1993 AASHTO "Guide for Design of Pavement Structures" and the AASHTO pavement design software DARWin Version 3.01, 1993, are used to determine pavement designs.

The department uses different accumulated ESAL values for pavement design depending on the selected pavement fix and the corresponding design life. Typical design lives are as follows:

Pavement Fix	Design Life and Length of Accumulated ESAL's (Years)
New/Reconstructed Rigid and Flexible Pavements	20
HMA over Rubblized Concrete	20
Unbonded Concrete Overlay over Repaired Concrete	20
HMA on Aggregate Grade Lift	15 to 20
HMA over Crush & Shaped Base	10 to 15
Mill & HMA Resurface on a Flexible Pavement	10 to 15
Repair and HMA Resurface on a Flexible Pavement	10 to 15
Repair and HMA Resurface on Composite or Concrete	10 to 12
Mill and HMA Resurface on Composite or Concrete	10 to 12

The pavement designer should request the appropriate Design ESAL's from the Bureau of Planning. Design ESAL's are determined from traffic data that is collected at or near the site of the proposed project. The Department has both Weigh-In-Motion (WIM) sites and Permanent Traffic Recorder (PTR) sites located throughout the state. Data from these sites is used to determine traffic volumes, traffic growth rates and vehicle mix at a specific location. Vehicle mix includes percentage of trucks, percentage of cars and vehicle classification data. Vehicle classification further divides truck data based on axle configuration.

Soils information is also an important part of an accurate pavement design. A soils investigation should be performed to determine subgrade soil type and support characteristics. Portions of the existing pavement section such as granular base and aggregate base condition should also be investigated if the pavement alternative being considered will utilize the existing bases. The soils analysis may include information from pavement cores along with Falling Weight Deflectometer (FWD) data. The Pavement Designer should request this analysis from the Region Soils Specialist. The Region Soils Specialist is responsible for supplying all pertinent information to the Pavement Designer including a subgrade Resilient Modulus value to use in pavement design calculations.

The AASHTO pavement design procedure uses several other inputs to determine a proper pavement design. Recommended values are listed below:

<u>All Pavement Types</u>

1. Initial Serviceability - 4.5

2. Terminal Serviceability - 2.5

3. Reliability Level - 95%

<u>Flexible Pavements</u>

1. Roadbed Soil Resilient Modulus: Use "Falling Weight Deflectometer"(FWD) data when possible, otherwise a value is chosen based on the predominant subgrade soil type. A correlation can be made between soil type and Resilient Modulus.

2. Overall Standard Deviation - 0.49

3. Structural Coefficients:

HMA Top & Leveling Course	0.42
HMA Base Course	0.36
Rubblized Concrete	0.18
Crush & Shaped HMA	0.20
Aggregate Base	0.14
Sand Subbase	0.10
ASCRL & Stabilized Base	0.30

4. Elastic Modulus:

HMA Top & Leveling Course	390,000 – 410,000 psi
HMA Base Course	275,000 – 320 000 psi
Rubblized Concrete	45,000 – 55,000 psi
Crush & Shaped HMA	100,000 – 150,000 psi
Aggregate Base	30,000 psi
Sand Subbase	13,500 psi
ASCRL & HMA Stabilized Base	160,000 psi

5. Drainage Coefficient:

(See Table 2.4, page II-25, AASHTO Guide for Design of Pavement Structures)

HMA Top & Leveling Course	1
HMA Base Course	1
Rubblized Concrete	1
Crush & Shaped HMA	1
Aggregate Base	1
Sand Subbase	1

6. Stage Construction - 1

Rigid Pavements

1. 28-day mean PCC Modulus of rupture - 670 psi

2. 28-day mean Elastic Modulus of Slab - 4,200,000 psi

3. Mean Effective k-value (psi/in): Use AASHTO's chart for "Estimating Composite Modulus of Subgrade Reaction" and "Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support". Figures 3.3 and 3.6 in AASHTO's 1993 Guide for Design of Pavement Structures:

Typical Range: 50 – 200 psi/in

4. Overall Standard Deviation: Use 0.39

5. Load Transfer Coefficient, J: 2.7 for tied shoulder or widened lane (14')
3.2 untied shoulders

6. Overall Drainage Coefficient: 1 to 1.05

7. Effective Existing Pavement Thickness (Condition Survey Method): Pavement management condition data is used as an aid but a site review of the existing pavement and the planned amount of joint work to be done prior to the concrete overlay must be obtained.

CHAPTER 4. PAVEMENT SELECTION PROCESS

Pavement selection is determined using the life cycle cost analysis method when the project pavement costs exceed one million dollars. Pavement costs are determined by calculating the cost of the HMA and concrete necessary for paving the mainline pavement. When the cost of either the HMA or concrete exceeds $1 million a life cycle cost analysis is required.

The process required for projects meeting these criteria is as follows:

Step 1 - Each Region Office identifies mainline pavement costs for upcoming projects in that Region. The Associate Region Engineer (Development) requests a pavement selection analysis from either the Region pavement designer or the Lansing Pavement Management Unit, using the following guidelines:

> The Lansing Pavement Management Unit is responsible for preparing a pavement design and selection package for the following project types:
> a) All new/reconstruction projects with mainline pavement costs greater than $1 million.
> b) Major rehabilitation projects (unbonded concrete overlays & rubblized with HMA surfacing) with mainline pavement costs greater than $1 million.
>
> The Region pavement designer is responsible for preparing a pavement design and selection package for the following project types:
> a) Rehabilitation projects (other than major rehabilitations)
> b) Local roads being redesigned due to an MDOT project. Pavement designs for local roads require the concurrence of the local agency.
> c) New, reconstruction and major rehabilitation projects when the mainline pavement cost is less than $1 million.

Steps 2-5 pertain to projects where pavement selection is the responsibility of the Lansing Pavement Management Unit. Otherwise, assistance will be given to the Regions on an as- needed basis.

Step 2 - The appropriate Region personnel will request, assemble and provide all necessary information for projects requiring the Pavement Management Unit to prepare the pavement design and Life Cycle Cost Analysis. This information includes existing soils information, traffic data, maintenance of traffic scheme, as well as other miscellaneous information listed on the Life Cycle Cost Analysis Checklist, found in the appendix.

Step 3 - The pavement designer prepares multiple pavement designs to be used in the Life Cycle Cost Analysis (LCCA). A design life is selected based on the pavement fix life that is assigned to the project in the Region or Statewide program. The alternates considered should include both a concrete and HMA alternate. In the event that either a standard concrete or HMA alternate do not exist for the specified fix life, the pavement designer will consider multiple pavement alternates using the same surfacing material.

Step 4 - The pavement designer submits design alternates to the Pavement Selection Engineer, who prepares the LCCA package. The LCCA package should include:

-A cover memo indicating the alternate with the lowest life cycle cost and a project summary explaining the project location, existing and proposed typicals, existing pavement condition (including RSL and RQI), traffic volumes, construction staging and maintaining traffic scheme.

-An appendix should also be attached which includes all of the detailed information that was used in the analysis. Items such as unit prices, production rates, soil boring logs and recommendation memos, traffic memos, construction scheduling analysis, pavement design information and life cycle cost calculations should all be included in the appendix.

Step 5 - The Pavement Management Engineer along with the Pavement Selection Engineer, Lansing Pavement Design Engineer and any other necessary Lansing/Region personnel review the pavement selection package. Corrections, if necessary, are made, and an updated package is forwarded to the Engineering Operations Committee (EOC) for a preliminary review. Once the LCCA package is preliminarily approved, it is sent out for industry review. Again, corrections, if any, are made, and the final package is submitted to EOC for final review and approval.

The Engineering Operations Committee approves the pavement selection based on the alternate that has the lowest life cycle cost. EOC is the senior technical committee in MDOT. The committee membership includes the Chief Engineer, representatives from the Design Division, Construction & Technology Division, Maintenance Division, Traffic & Safety Division, Region Offices and the Federal Highway Administration. The committee is chaired by the Chief Operations Officer.

Step 6 - Region Office or Bureau of Planning finalize the Scope of Work for the proposed project.

Step 7 - Region or Bureau of Planning program the project and the project is assigned to a Design Engineer with a Plan Completion Date

Projects having pavement costs less than one million dollars are not required to follow the above process. However, the pavement designer should use some form of objective analysis for these projects to determine pavement type selection. The analysis technique should document that the decision supports cost-effective use of the Department's pavement preservation dollars.

CHAPTER 5. COMPONENTS OF A LIFE CYCLE COST ANALYSIS

A. Economic Analysis Approach

LCCA is used to compare the relative long term costs of different pavement alternatives. LCCA allows the Engineer to objectively evaluate costs of two or more rehabilitation and/or reconstruction alternatives that may have significantly different initial costs and require very different levels of future preventive maintenance expenditures.

The analysis is expressed in terms of Equivalent Uniform Annual Costs (EUAC). Costs are annualized in order to compare alternates that have different Service Lives. The Service Life for each pavement fix has been determined using actual Department pavement maintenance records. A pavement Service Life is defined as the amount of time (expressed in years) before the pavement is in need of a subsequent rehabilitation or reconstruction. Service Life values can vary significantly based on the type of original rehabilitation or reconstruction method.

Historical maintenance data is also used to identify what maintenance expenditures actually occur throughout the Service Life of each rehabilitation or reconstruction fix. This data along with PMS performance data is used to develop Pavement Preservation Strategies (Chapter 7) that reflect real pavement performance and the associated maintenance costs. These Pavement Preservation Strategies are used to define the basis for the Life Cycle Cost Analysis.

Future costs are discounted to their present value and annualized over the Service Life, which allows the Engineer to compare different alternatives. Real discount rates are used in the analysis and no correction is made for inflation. Recommended discount rates are published yearly by Federal Government's Office of Management and Budget. A real discount rate quantifies the rate of return that the agency could receive if future needed maintenance dollars were invested at the time of initial construction.

All life-cycle costs will be expressed in current-year dollars; that is, at prices prevailing at the time of the decision. The discount rate contains no component for inflation since real discount rates are used. Price data is based on the Department's bidding records.

All costs are reported on a per mile basis for the entire roadway typical on bidirectional roadways (e.g. east & west-bound M-57), while costs are computed per directional mile on divided highways (e.g. one bound of I-75).

B. Initial Agency Costs

Only costs that differ between alternates are considered in the calculation. Initial agency costs may include cost items such as mainline pavement, shoulders, joints, subbase, base, underdrains,and traffic control. Unit prices will be determined from past MDOT projects and will be based on the weighted average of low bid data. The procedure used for unit price determination is further explained in the Data Updates (see Chapter 8).

C. Initial User Costs

Initial user costs will be based on daily and hourly traffic volumes, possible detour routes, capacity, and construction work days. A memo outlining the maintaining traffic/stage construction scheme should be drafted for the Region Engineer's signature. Maintaining traffic schemes will be approved by the Region Engineer. The process requires that the Regions submit a memo outlining the maintaining traffic/stage construction scheme that will be used to construct the project. This information is required to calculate user costs and maintaining traffic costs for the various alternatives being considered in the analysis. The contents of the memo will include items such as:

-temporary widening requirements for maintaining traffic
-number of lanes open to traffic during construction
-any restrictions on operating hours, i.e., night work only, northbound-Friday/southbound-Monday, weekday work only, etc.
-number and length of allowable lane closures
-detour route (if applicable)
-differences to scheme (staging & cost) whether a HMA or concrete section is constructed

The submitted maintaining traffic scheme will be based on what the Region determines will be the actual maintaining traffic plan when the project is eventually constructed. The Region Engineer will send a memo to the Pavement Engineer, Pavement Management Unit, explaining the anticipated maintaining traffic scheme.

D. Future Agency (Maintenance) Costs

Maintenance costs are based on MDOT maintenance records. Historical maintenance data and pavement condition data from the pavement management system have been used to develop maintenance costs schedules otherwise termed “Pavement Preservation Strategies” for the various pavement fixes (see Chapter 7).

E. Future User Costs for Maintenance Activities

User costs for maintenance activities are selected based on Table A, found in Chapter 7.

The tabulated user cost data is based on conducting the most time consuming preventive maintenance treatment that is typically performed on a HMA and concrete pavement. The specific work activity for concrete is concrete patching while the work activity used for HMA is a one course resurfacing.

This simplified approach for determining user costs for future maintenance was developed to minimize the analysis time while still considering future user costs. As can be seen in LCCA examples in the Appendix, user costs for future maintenance are very small dollar amounts versus other costs in the analysis. The quality of the analysis is not adversely affected by making conservative estimates of future user costs.

CHAPTER 6. SOFTWARE

Several tools have been developed which can assist the Engineer in doing a pavement design and a pavement selection analysis. The tools have been developed to minimize the time required to perform an analysis and also maintain uniformity in the analysis method.

Pavement design software titled "DARWin Version 3.01" is used by the Department to conduct pavement designs. This software was developed by AASHTO to compliment the 1993 version of the AASHTO Guide for Design of Pavement Structures.

User cost analysis software has also been developed by MDOT to aid traffic engineers in performing the user cost analysis portion of a pavement selection analysis. This software titled "Construction Congestion Cost (CO3)" is based on the user cost analysis method recommended by the Federal Highway Administration (FHWA). This method is explained in the FHWA Interim Technical Bulletin titled "Life Cycle Cost Analysis in Pavement Design".

Project costing software has also been developed which calculates initial agency costs that are included in the life cycle cost analysis. This software uses stored unit price data for all applicable work items, and user input data for each design alternative, to calculate initial costs.

See the Pavement Management Unit contact sheet in this manual regarding questions concerning these software packages.

CHAPTER 7. PAVEMENT PRESERVATION STRATEGIES

Pavement preservation strategies are shown in this chapter. These strategies (maintenance schedules) reflect the overall maintenance approach that has been used network-wide for a specific fix based on historical maintenance and pavement management records.

Pavement Preservation Strategy

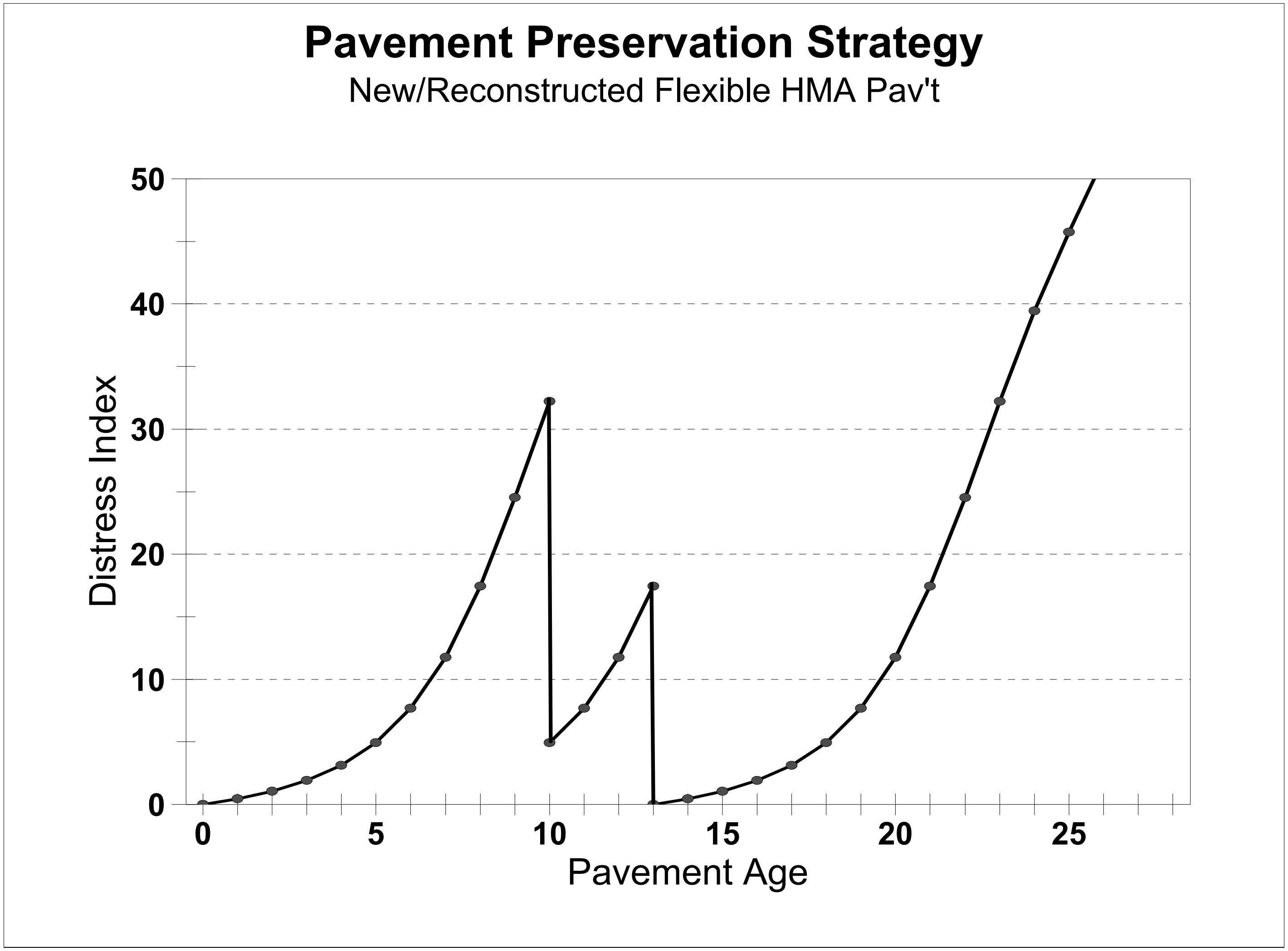
Facility: Freeway/ Divided Highway
Fix Type: New/Reconstruction - Flexible HMA Pavement

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			13	Computed Computed	Agency User Cost
Prev. Maintenance	29	6	10	3	5	8	$33,789 See Table A	Agency* User Cost
Prev. Maintenance	18	0	13	5	8	13	$44,730 E10 $54,384 E30 $52,293 E50 See Table A	Agency** Agency** Agency** User Cost
Rehabilitation or Reconstruction			26					

Equivalent Uniform Annual Cost (EUAC) = NPV ($i (1+i)^n) / ((1+i)^n - 1)$

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / $(1+i)^n$
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs



Pavement Preservation Strategy
New/Reconstructed Flexible HMA Pav't
Distress Index
Pavement Age
50
40
30
20
10
0
0
5
10
15
20
25

Pavement Preservation Strategy

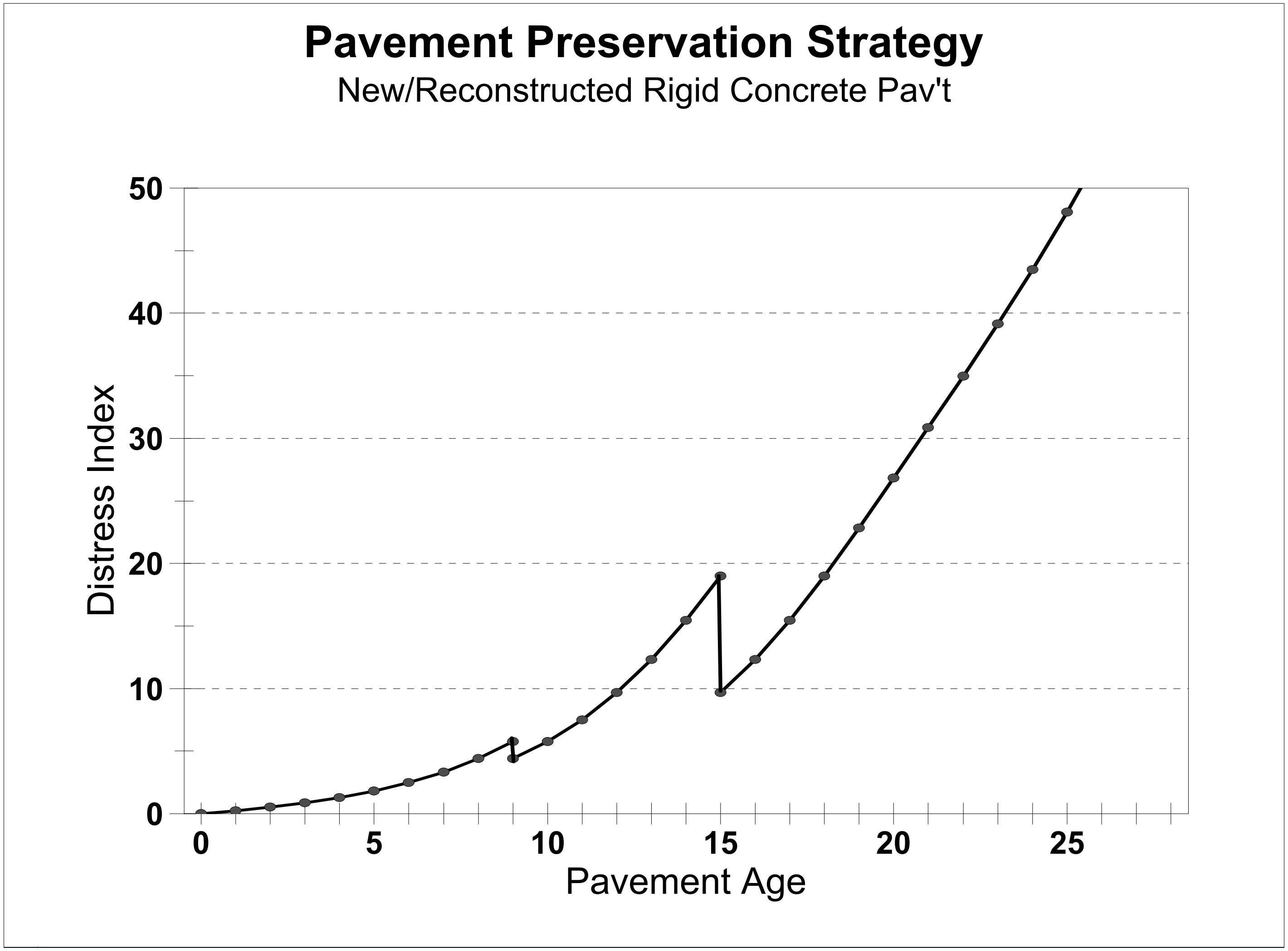
Facility: Freeway/ Divided Highway
Fix Type: New/Reconstruction - Rigid Concrete Pavement

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			22	Computed Computed	Agency User Cost
Prev. Maintenance	6	5	9	13	1	14	$13,516 See Table A	Agency* User Cost
Prev. Maintenance	18	10	15	8	3	11	$41,834 See Table A	Agency** User Cost
Rehabilitation or Reconstruction			26					

Equivalent Uniform Annual Cost (EUAC) = NPV (i (1+i) ^{n}) / ((1+i)^{n} - 1)

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / (1+i)^{n}
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs


Pavement Preservation Strategy
New/Reconstructed Rigid Concrete Pav't
Distress Index
50
40
30
20
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0
0
5
10
15
20
25
Pavement Age

Pavement Preservation Strategy

Facility: Freeway/ Divided Highway
Fix Type: Rehabilitation - Unbonded Concrete Overlay on Repaired Concrete

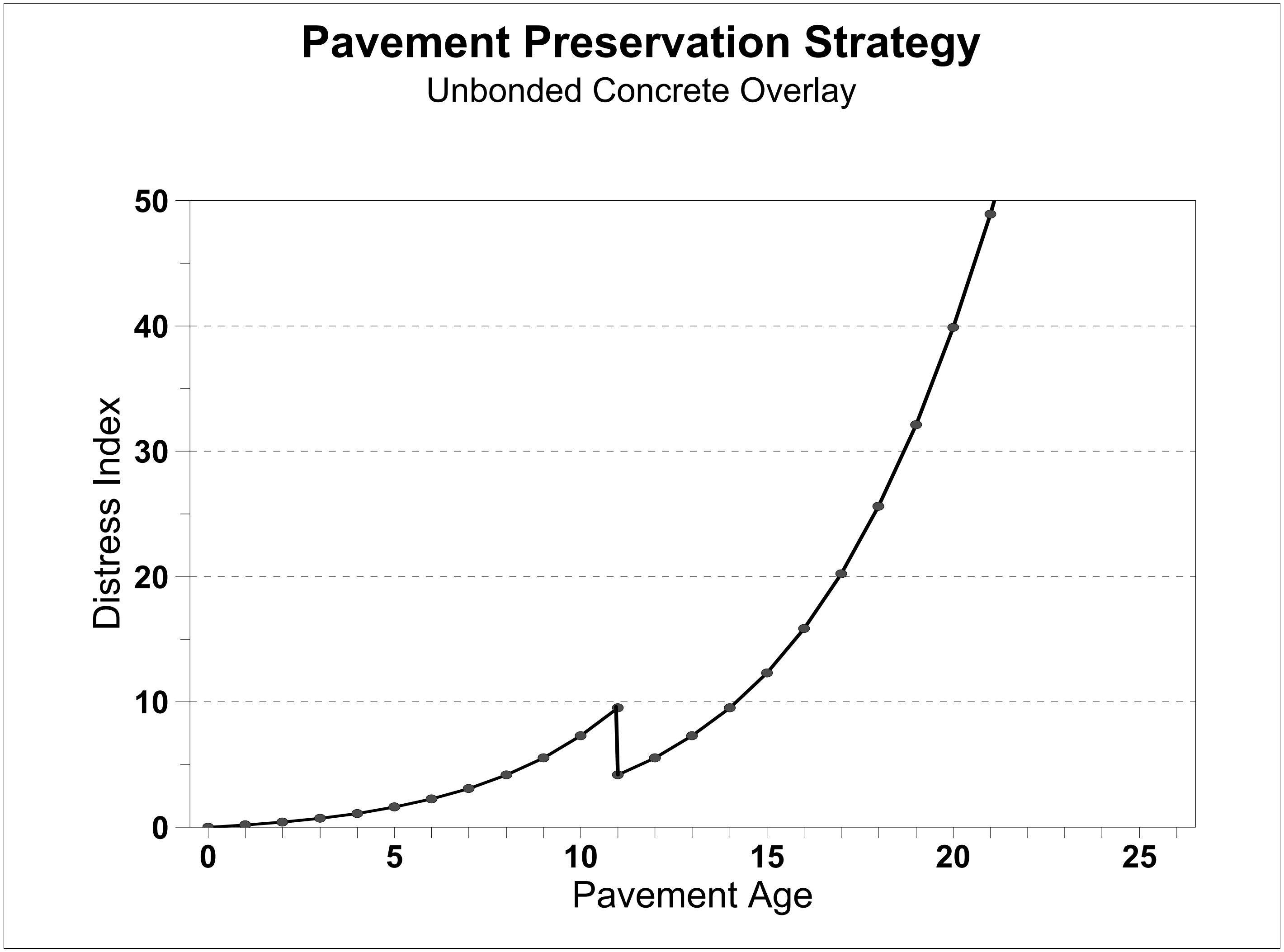
Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			18	Computed Computed	Agency User Cost
Prev. Maintenance	10	3	11	7	3	10	$25,905 See Table A	Agency* User Cost
Rehabilitation or Reconstruction			21					

Equivalent Uniform Annual Cost (EUAC) = NPV (i $(1+i)^n$) / ($(1+i)^n$ - 1)

* based on actual mainterance costs

Net Present Value (NPV) = Initial Construction + (Maintenance) / $(1+i)^n$
i = Real Discount Rate (2005: 3.1%)

Pavement Preservation Strategy



Pavement Preservation Strategy

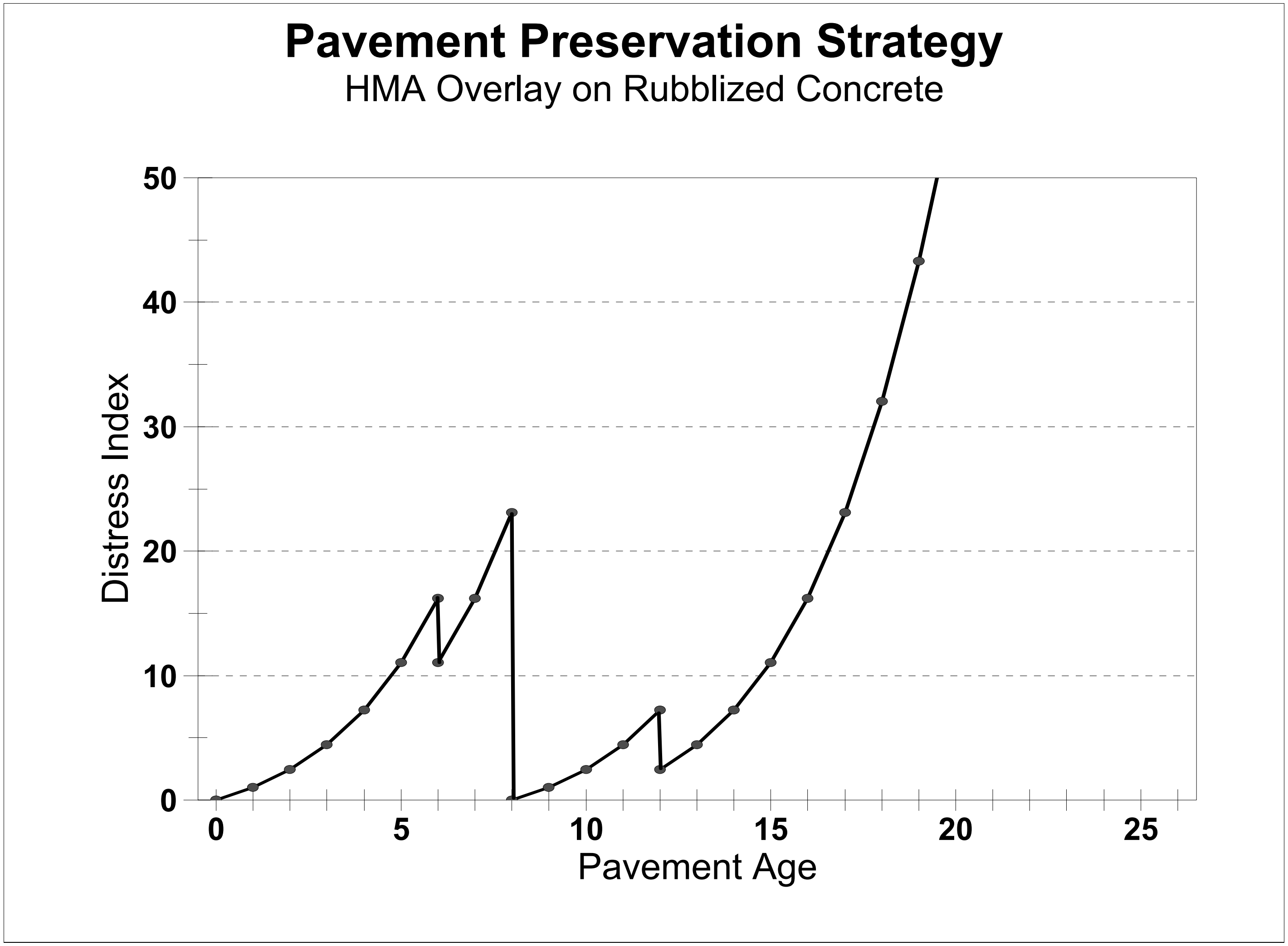
Facility: Freeway/ Divided Highway
Fix Type: Rehabilitation - HMA Overlay on Rubblized Concrete

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			10	Computed Computed	Agency User Cost
Prev. Maintenance	17	15	6	4	1	5	$20,273 See Table A	Agency* User Cost
Prev. Maintenance	23	0	8	3	7	10	$46,661 E10 $56,315 E30 $54,384 E50 See Table A	Agency** Agency** Agency** User Cost
Prev. Maintenance	7	2	12	6	2	8	$4,827 See Table A	Agency* User Cost
Rehabilitation or Reconstruction			20					

Equivalent Uniform Annual Cost (EUAC) = NPV ($i\,(1+i)^{n}$) / ($(1+i)^n - 1$)

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / $(1+i)^n$
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs


Pavement Preservation Strategy
HMA Overlay on Rubblized Concrete
Distress Index
50
40
30
20
10
0
0
5
10
15
20
25
Pavement Age

Pavement Preservation Strategy

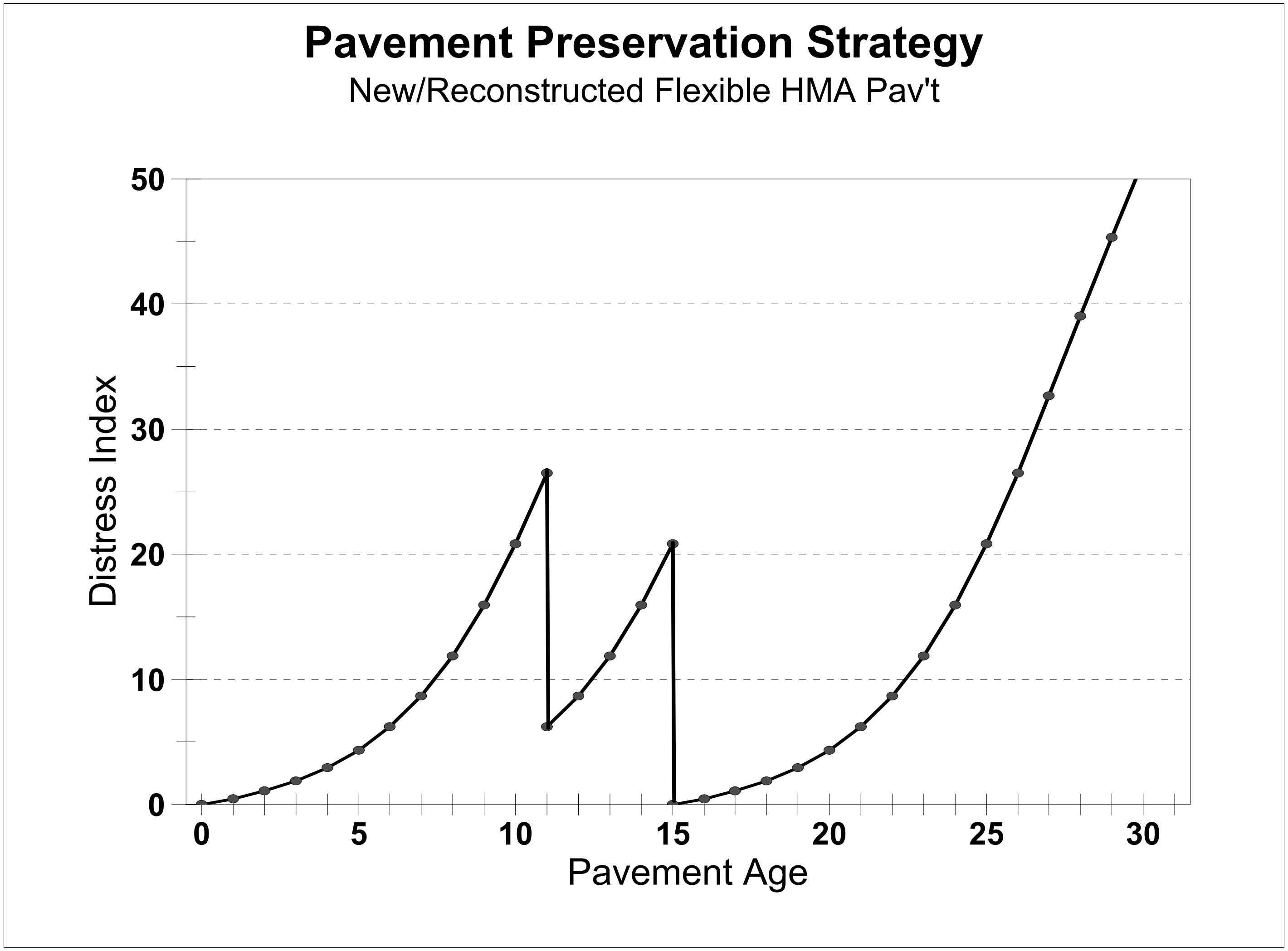
Facility: Low Volume
Fix Type: New/Reconstruction - Flexible HMA Pavement

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			15	Computed Computed	Agency User Cost
Prev. Maintenance	27	7	11	4	5	9	$22,204 See Table A	Agency* User Cost
Prev. Maintenance	20	0	15	5	10	15	$44,891 E3 $45,696 E10 $55,350 E30 See Table A	Agency** Agency** Agency** User Cost
Rehabilitation or Reconstruction			30					

Equivalent Uniform Annual Cost (EUAC) = NPV $(i (1+i)^n) / ((1+i)^n - 1)$

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / $(1+i)^n$
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs


Pavement Preservation Strategy
New/Reconstructed Flexible HMA Pav't
Distress Index
50
40
30
20
10
0
0
5
10
15
20
25
30
Pavement Age

Pavement Preservation Strategy

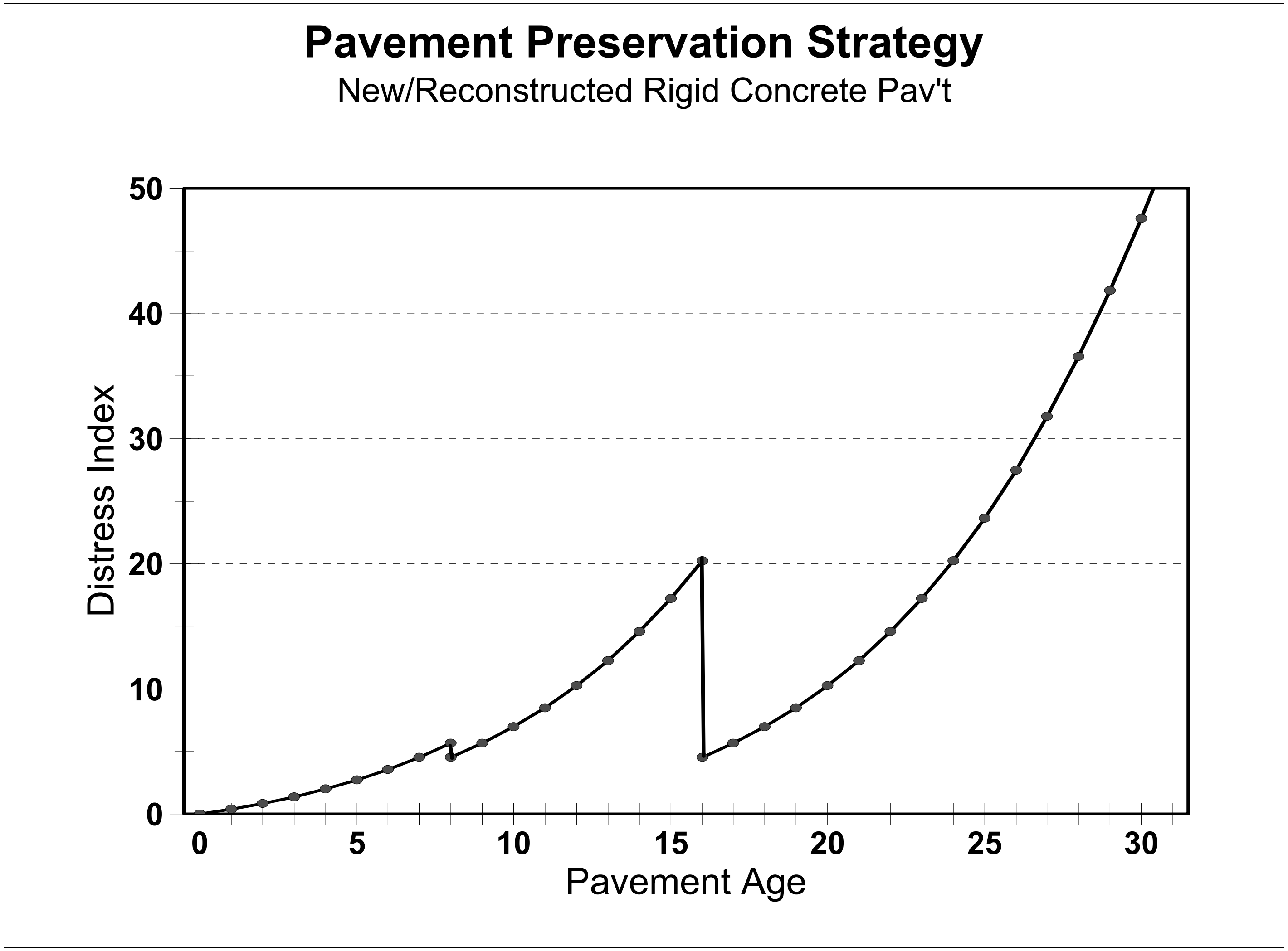
Facility: Low Volume **(Combined projects with Freeway)**
Fix Type: New/Reconstruction - Rigid Concrete Pavement

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			21	Computed Computed	Agency User Cost
Prev. Maintenance	6	5	8	13	1	14	$13,516 See Table A	Agency* User Cost
Prev. Maintenance	20	5	16	6	8	14	$65,647 See Table A	Agency** User Cost
Rehabilitation or Reconstruction			30					

Equivalent Uniform Annual Cost (EUAC) = NPV (i (1+i) ^{n}) / ((1+i)^n - 1)

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / (1+i)^n
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs


Pavement Preservation Strategy
New/Reconstructed Rigid Concrete Pav't
Distress Index
0
10
20
30
40
50
0
5
10
15
20
25
30
Pavement Age

March 7, 2005

Pavement Preservation Strategy

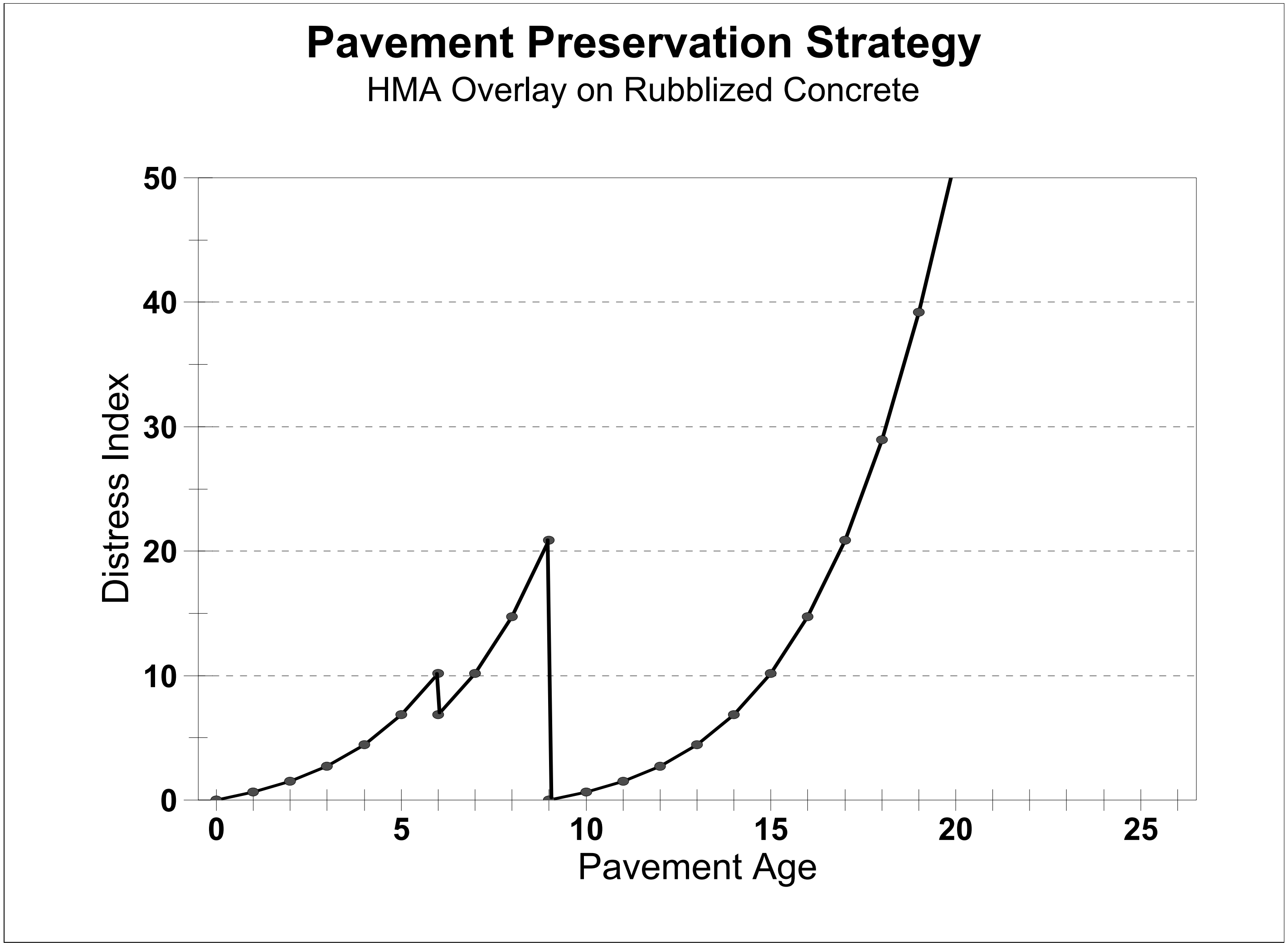
Facility: Low Volume **(Combined projects with Freeway)**
Fix Type: Rehabilitation - HMA Overlay on Rubblized Concrete

Activity	Distress Index (Before)	Distress Index (After)	Approx. Age	RSL (yrs) (Before Fix)	Life (yrs) Extension	RSL (yrs) (After Fix)	Cost per Lane-Mile	
Initial Construction	0		0			11	Computed Computed	Agency User Cost
Prev. Maintenance	10	6	6	5	1	6	$27,192 See Table A	Agency* User Cost
Prev. Maintenance	20	0	9	3	8	11	$44,891 E3 $45,696 E10 $55,350 E30 See Table A	Agency** Agency** Agency** User Cost
Rehabilitation or Reconstruction			20					

Equivalent Uniform Annual Cost (EUAC) = NPV $(i (1+i)^{n}) / ((1+i)^{n} - 1)$

Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / $(1+i)^{n}$
i = Real Discount Rate (2005: 3.1%)

* based on actual maintenance costs
** based on assumed maintenance costs



Pavement Preservation Strategy
HMA Overlay on Rubblized Concrete
Distress Index
Pavement Age
0
10
20
30
40
50
0
5
10
15
20
25

TABLE A
User Costs for Maintenance Activities

Total ADT	Facility	User $/day	Day/ln-mile		Day/ln-mile	Bituminous	Concrete
			Bit		Concrete	User $/ln-mile	User $/ln-mile
0 to 40,000	Fwy.*	$191	0.35		0.6	$67	$115
40,001 to 80,000	Fwy.*	$321	0.35		0.6	$112	$193
80,001 to 120,000	Fwy.*	$658	0.35		0.6	$230	$395
0 to 40,000	Divided Hwy.*	$288	0.35		0.6	$101	$173
40,001 to 80,000	Divided Hwy.*	$489	0.35		0.6	$171	$293
80,001 to 120,000	Divided Hwy.*	$909	0.35		0.6	$318	$545

* User costs based on a one lane closure.

Computations:

Maintenance for HMA

1 lane-mile @ 165 lbs/syd (12 ft/lane)
Production = 1650 Ton/day
(165 lbs/syd x 12 ft/ln x 5280 ft/mile x syd/9 sft)/(2000 lbs/Ton) = 581 Ton/ln-mile
(581 Ton/ln-mile)/1650 Ton/day = 0.35 day/ln-mile

Maintenance for Concrete

1 lane-mile @ 30 patches/ln-mile
Production = 50 patches/day
(30 patches/ln-mile)/(50 patches/day) = 0.6 day/ln-mile

CHAPTER 8. DATA UPDATES

<u>Unit Prices</u>
Unit prices used in the pavement selection process are updated based on the following procedure:

Prices are updated on a semiannual basis. Prices will be published in February and August every year. The February publication will be based on price data ending with the prior December letting. The August publication will be based on price data ending with the prior June letting. Updated prices will be sent out to MCPA, MAPA and MPA approximately one month before the official published date for comment. However, the final decision for selected prices resides with MDOT. The updated unit prices will be used in any LCCA after the new prices are officially published (approximately February 15th and August 15th).

Unit prices will be determined from past MDOT projects only, no local agency projects, and will be based on the weighted average of low bid data when possible following steps 1-8 listed below. Unit prices will be determined for a geographical area except when steps 1-8 result in a statewide average price. There are three geographic areas that are considered. The three areas are: Superior/North Regions, Grand/Bay/Southwest Regions, and University/Metro Regions. Additionally, for a given hot mix asphalt mixture, there must be a minimum of 6000 tons on a project basis in order for it to be included in the data set.

The steps listed below are the order in which price data will be queried. Steps 1-4, & 7 are on a regional area basis. Steps 5, 6 & 8 are on a statewide basis. If a given unit price can not be obtained from the first step the query will proceed to the second and continue through the steps until a unit price can be obtained. When unit price data is not available for a specific work item, unit prices of similar work items will be considered in unit price determination as outlined in steps 7 & 8.

Steps are as follows:

1. 1 or more projects in the last 18 months with individual project threshold of 68,000 square yards of concrete pavement or 23,000 tons of hot mix asphalt.
2. 1 or more projects in the last 24 months with individual project threshold of 68,000 square yards of concrete pavement or 23,000 tons of hot mix asphalt.
3. 1 or more projects in the last 18 months with individual project threshold of 34,000 square yards of concrete pavement or 11,500 tons of hot mix asphalt.
4. 1 or more projects in the last 24 months with individual project threshold of 34,000 square yards of concrete pavement or 11,500 tons of hot mix asphalt.
5. Statewide weighted average of projects in the last 18 months that meet the individual project thresholds per Steps 1-4.
6. Statewide weighted average of projects in the last 24 months that meet the individual project thresholds per Steps 1-4.
7. Prorate the unit price for the next closest concrete thickness using both sides of the thickness within in a regional area. Calculate a unit price for the hot mix asphalt type by averaging the prices of adjacent hot mix asphalt types within a regional area.

8. Prorate the unit price for the next closest concrete thickness using both sides of the thickness on a statewide basis. Calculate a unit price for the hot mix asphalt type by averaging the prices of adjacent hot mix asphalt types on a statewide basis.

   Note: When querying hot mix asphalt the query will be for individual mix types on a project; i.e. the summation of 5E10, 4E10, 3E10, and 2E10 not the summation of 5E10, 4E10, 3E10, 2E10, 4C, 3C, and 2C.

Those projects which meet the criteria set forth in Steps 1-4 are compiled into a "qualified project list" for later use.

Common Items

Common items are those items that are neither a HMA mixture nor a mainline concrete pavement, but they are vital for successful pavement performance. Examples of common items would be all granular base materials, underdrains and pavement joints. See the most current LCCA Unit Price List for a complete listing of all common items used in the LCCA process.

To calculate a unit price for common items, first a "qualified project list" must be built based upon completing the previous steps for concrete pavements and HMA mixtures. The only common item prices that may be used in a weighted average price are those that are included in a project on the "qualified project list." A regional weighted average unit price for projects in the last 18 months is determined first. If prices are not available for the last 18 months, unit prices in the last 24 months are used. If a regional price cannot be determined, a weighted statewide average price is calculated. Finally, items with no bids in the last 24 months are prorated, and when applicable, averaged using both sides of the thickness, first on a regional basis, then on a statewide basis.

All Other Input Data

The real discount rate used in LCCA calculations is obtained from the Federal Office of Management and Budget, and is updated yearly, usually in February. For information on the current rate see: http://www.whitehouse.gov/omb/memoranda/index.html

All other input data used in the pavement selection process will be reviewed and updated at least every two years. Updates may occur sooner for some input items.

CHAPTER 9. DEFINITIONS

Rigid Pavement - a pavement with a concrete surface that is placed on either a granular, aggregate or stabilized base.

Flexible Pavement - a pavement with a HMA surface that is placed on either a granular, aggregate or stabilized base.

Composite Pavement - a pavement with a HMA surface that is placed on a concrete pavement.

Cost Effectiveness - A ratio of costs incurred to realize a pavement condition improvement over a specified period of time.

Life Cycle Cost Analysis - An economic analysis method that evaluates the long term costs of an investment alternative. The method can be used to compare the relative costs of various investment alternatives.

Network - A collection of pavements that have a common characteristic(s). These could include common traffic volumes, jurisdictional control, route designation, number of lanes, access control etc...

Distress Index - An index that quantifies the level of distress that exists on a pavement section based on 1/10 mile increments. The scale starts at zero and increases numerically as distress level increases (pavement condition worsens).

Threshold Distress Index - A pavement condition level where a rehabilitation or reconstruction should be considered. The threshold distress index is equal to fifty.

Remaining Service Life (RSL) - The estimated number of years, from a specified date in time, until a pavement section reaches the threshold distress index. RSL is a function of the distress level and rate of deterioration.

Ride Quality Index (RQI) - An index developed by Michigan that quantifies the user's perception of pavement ride quality. It is reported in tenth mile increments. The scale starts at zero and increases numerically as ride quality decreases.

Threshold Ride Quality Index - The threshold index for poor pavement ride quality is equal to seventy.

Ride Quality Index (RQI) Condition Ranges

Excellent	less than 30
Good	31 to 53
Fair	54 to 69
Poor	70 or greater

Poor Pavement - a pavement with an RSL of 0 to 2 years and/or an RQI of 70 or greater.

Fix Life - The anticipated pavement life provided by the fix, excluding any future preventive maintenance treatments.

Equivalent Single Axle Load (ESAL) - standard form of measurement used in pavement design to describe the damage caused by one pass of an 18,000 pound load.

Design Life - The anticipated life of the pavement section at the time of initial construction. Design life, as fix life, does not include any additional life estimates provided by anticipated future preventive maintenance. This term is also used to define the number of years for which design Equivalent Single Axle Loads are calculated as an input parameter for formal pavement design calculations.

Service Life (Analysis Period) - The anticipated life of a rehabilitation or new/reconstruction, including additional pavement life provided by anticipated future preventive maintenance. This term is used to describe the number of years from the initial new construction, reconstruction or rehabilitation of a pavement to a subsequent rehabilitation or reconstruction. A service life or analysis period equals the sum of the original design/fix life plus any additional pavement life provided by future anticipated preventive maintenance. Analysis period is the term typically used to describe the time used in a life cycle cost analysis.

Rehabilitation - A fix that has an estimated design or fix life of ten to twenty years. Rehabilitation fixes are typically applied to pavements with a remaining service life of two years or less. These fixes include: two or three course HMA overlays, concrete patching & diamond grinding, crush & shape with HMA overlay, rubblize & multiple course HMA overlay, and unbonded concrete overlays.

Reconstruction - Typically removes and replaces the entire pavement structure. Sometimes the sand subbase may be left in place and incorporated in the new pavement structure. Reconstruction projects have a design life of twenty years or more. This fix is typically applied to pavements with a remaining service life of two years or less.

Capital Preventive Maintenance – "Preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves, retards future deterioration and maintains or improves the functional condition of the system without (significantly) increasing structural capacity." Preventive maintenance is applied to pavements having a remaining service life of three years or greater. Examples of capital preventive maintenance include HMA crack sealing, chip sealing, micro-surfacing, concrete joint resealing, concrete crack sealing, thin HMA overlays, diamond grinding, full depth concrete repairs, and dowel bar retrofit.

REFERENCES

"Life Cycle Cost Analysis in Pavement Design", Federal Highway Administration Publication No. FHWA-SA-98-079, 1998.

"AASHTO Guide for Design of Pavement Structures", American Association of State Highway and Transportation Officials, 1993.

"DARWin Version 3.01", American Association of State Highway and Transportation Officials, 1997.

"Construction Congestion Cost (CO3)", Robert I. Carr, University of Michigan 1997.

"Recommended Method of Pavement Selection - Life Cycle Costing of New and Reconstructed Pavements", Michigan Department of Transportation, 1992.

"Recommended Method of Pavement Selection - Life Cycle Costing of Rehabilitated Pavements", Michigan Department of Transportation, 1995.

"OMB Circular Number A-94", Federal Office of Management and Budget, 1999.

CONTACT PEOPLE - PAVEMENT MANAGEMENT UNIT

Name	Title	Contact Information
Pat Schafer	Pavement Management Engineer	517-322-1766/SchaferPa@michigan.gov
Michael Eacker	Pavement Design Engineer	517-322-3474/EackerM@michigan.gov
Ben Krom	Pavement Selection Engineer	517-322-6855/KromB@michigan.gov

APPENDIX

Michigan Department of Transportation

Life Cycle Cost Analysis Checklist

Control Section:		Job Number:	Region:
Route:	Date:	Project Limits:	
Project Manager:			
BMP:			
EMP:		Project Length:	

Checklist of Required Information:
(Submit package to Ben Krom, Pavement Selection Engineer, Lansing C & T)

Soils:

* ☐ Signed soils memo including:
  - ☐ Resilient Modulus (M_R) recommendation and method used to obtain
  - ☐ Existing mainline pavement and shoulder section. Describe in memo or attach typicals.
  - ☐ Any recommendations to deviate from standard gradations and/or thickness in the base or subbase (new/reconstruct projects only)

☐ Soil borings (if available)

Traffic:

☐ Maintaining Traffic memo signed by the Region Engineer
Is the maintaining traffic scheme the same regardless of concrete or HMA pavement?
☐ Yes ☐ No (If no, detail each scheme, including cost differences)

* ☐ Traffic Information memo (including ADT, % commercial, growth rate, rigid & flexible ESAL's, etc.)
☐ 24 Hour traffic distribution (weekday and weekend if available)

Miscellaneous:

* Is there a grade change in the proposed plan grade?
☐ No ☐ Yes (if yes, what is the average height of cut or fill? ___________inches)

* What is the proposed lane & shoulder configuration and widths? (describe below or include attachment)

Any other circumstances which could influence the LCCA?

☐ Location/vicinity map

*Minimum information needed to perform a pavement design. Remainder required to perform LCCA.

Sample Pavement Selection Package

Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: March 7, 2005

TO: Brenda J. O'Brien
Engineer of Construction and Technology

FROM: Benjamin F. Krom
Pavement Selection Engineer

SUBJECT: **Pavement Selection: Reconstruct Jointed Plain Concrete Pavement**
CS 80012, 80013 & 03033, JN 60471
Rehabilitate I-196: From south of M-140 to south of 109th Avenue
CS 80012: BMP 8.950 to 9.670; CS 80013: 0.000 to 3.880;
CS 03033: 0.000 to EMP 4.300

I am requesting that the referenced project be placed on the agenda for the next Engineering Operations Committee (EOC) meeting. The subject project is programmed for letting in December of 2006 (May 2006 plan completion). This project will be designed using English units.

The reconstruction alternatives being considered are a Hot Mix Asphalt Pavement (Alt #1) and a Jointed Plain Concrete Pavement (Alt #2). For Alt #2, the existing subbase is suitable for retention and will be left in place. However, for Alt #1, due to the depth of the proposed section, the existing subbase must be replaced. The pavement designs being considered are as follows:

Alternative #1: Reconstruct with Hot Mix Asphalt Pavement

1.75"	Gap Graded Superpave, Top Course (mainline & inside shoulder)
2.5"	HMA, 4E30, Leveling Course (mainline & inside shoulder)
6.0"	HMA, 3E30, Base Course (mainline & inside shoulder)
1.75"	HMA, 4C (outside shoulder)
2.5"	HMA, 3C (outside shoulder)
3.0"	HMA, 2C (outside shoulder)
6.0"	Aggregate Base, 21AA, Mod (mainline & inside shoulder)
9.0"	Aggregate Base, 21AA, Mod (outside shoulder)
18.0"	Sand Subbase
6"	Underdrain System
34.25"	Total Section Thickness

Present Value Initial Construction Cost	$649,512/directional mile
Present Value Initial User Cost	$127,627/directional mile
Present Value Maintenance Cost	$123,125/directional mile

Equivalent Uniform Annual Cost (EUAC) $50,941/directional mile

<u>Alternative #2: Reconstruct with Jointed Plain Concrete Pavement</u>

11.0”	Jointed Plain Concrete Pavement w/ 15’ joint spacing (mainline)
	Freeway Shoulder Option
6.0”	Open Graded Drainage Course (mainline)
	Geotextile Separator
	Existing Sand Subbase
6”	Open-Graded Underdrain System
17.0”	Total Thickness

Present Value Initial Construction Cost	$578,507/directional mile
Present Value Initial User Cost	$113,766/directional mile
Present Value Maintenance Cost	$73,785/directional mile

Equivalent Uniform Annual Cost (EUAC) $43,347/directional mile

The pavement designs for both alternatives are based on the 1993 AASHTO “Guide for Design of Pavement Structures” and use the AASHTO pavement software DARWin Version 3.01, 1997. The Equivalent Uniform Annual Cost calculation is based on the revised pavement selection process as approved by the EOC on June 3, 1999.

The estimated construction costs are based on historical averages from similar projects. User costs are calculated using MDOT’s Construction Congestion Cost model, which was developed by the University of Michigan.

<u>Conclusion</u>
Pavement selection was determined using the procedures outlined in the MDOT Pavement Design and Selection Manual. Department policy requires that the pavement alternative with the lowest EUAC, **Alternative #2: Reconstruct with Jointed Plain Concrete Pavement**, be selected. Final pavement selection requires approval by the Engineering Operations Committee.

<u>SIGNED COPY ON FILE</u>
Pavement Selection Engineer

cc: C. Bleech
K. Kennedy
P. Schafer
M. Eacker
K. Rudlaff

PROJECT SUMMARY

Project Location

This project includes 8.9 miles of I-196 reconstruction from 0.7 miles south of M-140 to 0.5 miles south of 109th Avenue. The existing section is a 4 lane divided freeway consisting of 12' paved driving lanes, a 6' paved inside shoulder, and a 10' paved outside shoulder. The proposed section will consist of a 14' paved outer lane, a 12' paved inside lane, a 4' inside shoulder, and an 8' outside shoulder.

Existing Pavement and Condition Data

The existing typical cross section consists of, on average, 9" of jointed reinforced concrete pavement, 4" of aggregate base and 14" of sand subbase. The existing sand is suitable for retention.

Average Ride Quality (2003)	Average Remaining Service Life (2004)
RQI ≥ 70 Poor	RSL < 3 Poor
76 EB I-196	1 EB I-196
76 WB I-196	4 WB I-196

Traffic

22,300 ADT (2007 two-way)
6,690 Commercial ADT (2007 two-way)
Growth Rate: 1.5% compound
22.2 million Design ESAL's – Rigid – 20 years
16.5 million Design ESAL's – Flexible – 20 years
Directional Distribution Factor – 50%

Different 18 Kip axle equivalency factors (ESAL's) are used for the designs of Flexible and Rigid pavements because each pavement type experiences a different loss of serviceability from the passage of identical vehicles. Work done at the AASHO test road resulted in the creation of pavement design formulas that account for these differences. Proper use of these formulas requires that different ESAL's be used for Flexible and Rigid pavements, although the anticipated traffic is identical. The Engineering Operations Committee has approved the use of different ESAL factors for Flexible and Rigid pavement designs.

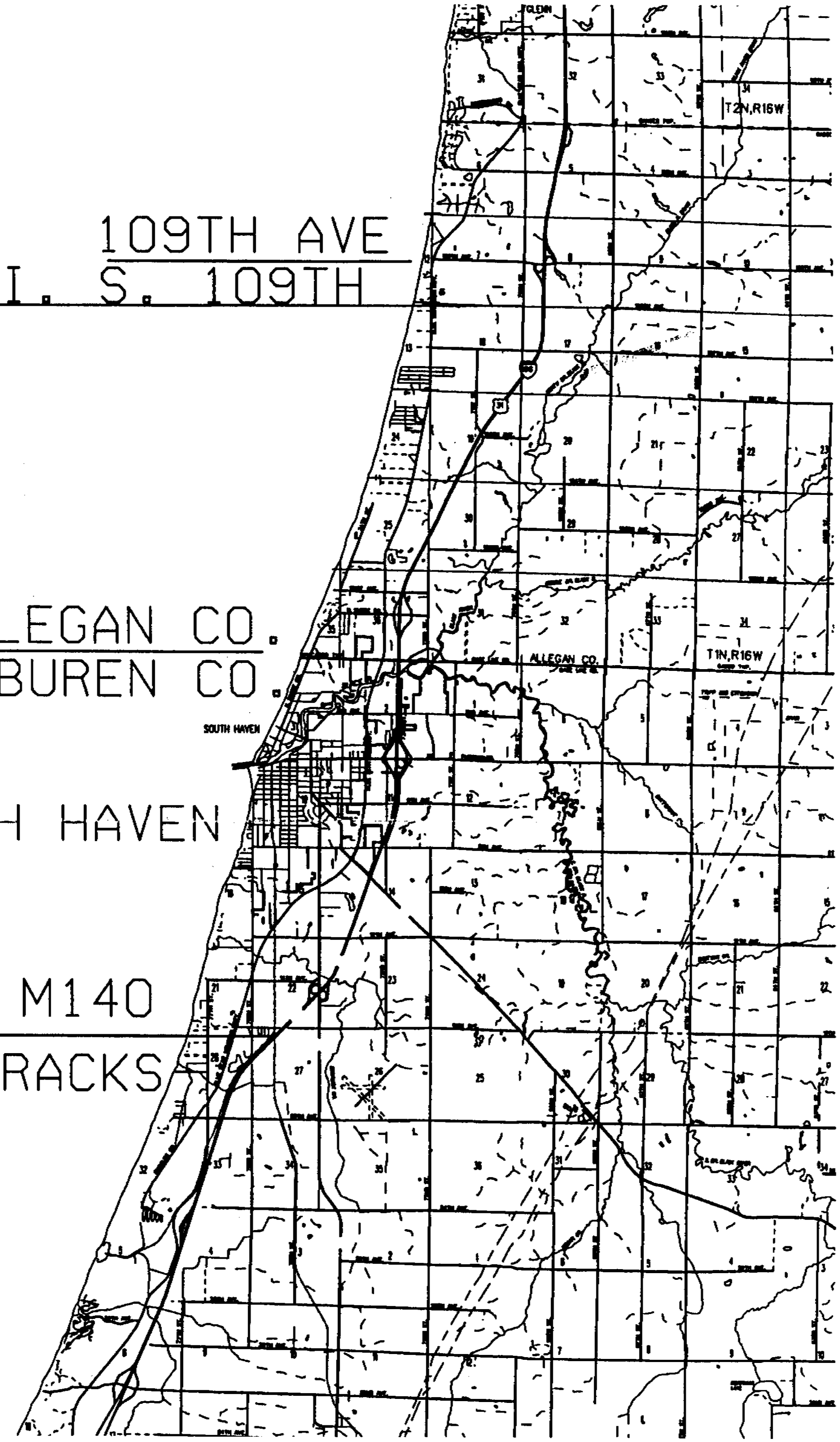
Hourly volumes for 24 hour periods, shown in the appendix, are based on distributions appearing in Table 3.2 of FHWA publication "Life Cycle Cost Analysis in Pavement Design". User costs for succeeding maintenance activities are based on the values shown in Table A, page 16, of the appendix.

Soils

The Regional Soils Engineer recommends a subgrade soil resilient modulus of 4,150 psi be used for design purposes. This is based on an analysis of the soil borings. For more information, refer to pages 19 of the appendix.

Construction Staging and Maintaining Traffic

For information refer to the maintaining traffic memo in the appendix.



109TH AVE

I-196 POE 0.5 MI. S. 109TH

ALLEGAN CO.

VAN BUREN CO.

SOUTH HAVEN

I-196 POB 0.7 MI. S. OF M140

BRIDGE OVER ABANDON RR. TRACKS

APPENDIX A – TABLE OF CONTENTS

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EUAC Summary

I-196 Reconstruction

Alternative	PV Initial Construction Cost	PV Initial User Cost	PV Maintenance Cost	n	EUAC
#1: HMA	$649,512	$127,627	$123,125	26	**$50,941**
#2: JPCP	$578,507	$113,766	$73,785	26	**$43,347**

EUAC = NPV*(i*(1+i)^n/((1+i)^n-1))

Note: All costs are per directional mile
NPV = Net Present Value
i = Real Discount Rate (2005: 3.1%)
n = Number of years
PV = Present Value
EUAC = Equivalent Uniform Annual Cost

PROJECT COSTING ALTERNATIVE #1: HMA PAVEMENT

REGION NO.	CONTROL SECTION	JOB NUMBER	BMP	EMP		LETTING DATE	PROJECT DESCRIPTION:
5	03033	60471	8.950	4.300		1-Dec-2006	I-196: From south of M-140 to south of
Southwest			Length =	8.900	Miles		109th Ave

PAY ITEM CODE	PAY ITEM DESCRIPTION	LANE (0=OS, 1=ML1, 2=ML2,…, 6=IS)		WIDTH (Ft)	DEPTH (Inches)	# OF RUNS or Jt SPACE (Ft)	ENTER QUANTITY	UNITS	CALC'D QUANTITY	UNIT PRICE	TOTAL COST (Per Dir. Mile)
											$649,511.69
5020032	HMA, 4C	Outside Shoulder	0	8	1.75			Ton	451.7	$34.33	$15,508.01
5020031	HMA, 3C	Outside Shoulder	0	8	2.5			Ton	645.3	$36.50	$23,554.67
5020030	HMA, 2C	Outside Shoulder	0	8	3			Ton	774.4	$34.50	$26,716.80
3020022	Aggregate Base, 9 inch	Outside Shoulder	0	8				Syd	4693.3	$5.53	$25,954.13
3010002	Subbase, CIP	Outside Shoulder	0	8	18			Cyd	2346.7	$4.31	$10,114.13
2050016	Excavation, Earth	Outside Shoulder	0	8	25.25			Cyd	3291.9	$1.79	$5,892.41
5027031	Gap-Graded Superpave	MainLine1	1	14	1.75			Ton	790.5	$48.77	$38,554.31
5020053	HMA, 4E30	MainLine1	1	14	2.5			Ton	1129.3	$36.77	$41,525.59
5020047	HMA, 3E30	MainLine1	1	14	6			Ton	2710.4	$40.40	$109,500.16
3020016	Aggregate Base, 6 inch	MainLine1	1	14				Syd	8213.3	$4.29	$35,235.20
3010002	Subbase, CIP	MainLine1	1	14	18			Cyd	4106.7	$4.31	$17,699.73
2050016	Excavation, Earth	MainLine1	1	14	25.25			Cyd	5760.7	$1.79	$10,311.73
5027031	Gap-Graded Superpave	MainLine2	2	12	1.75			Ton	677.6	$48.77	$33,046.55
5020053	HMA, 4E30	MainLine2	2	12	2.5			Ton	968.0	$36.77	$35,593.36
5020047	HMA, 3E30	MainLine2	2	12	6			Ton	2323.2	$40.40	$93,857.28
3020016	Aggregate Base, 6 inch	MainLine2	2	12				Syd	7040.0	$4.29	$30,201.60
3010002	Subbase, CIP	MainLine2	2	12	18			Cyd	3520.0	$4.31	$15,171.20
2050016	Excavation, Earth	MainLine2	2	12	25.25			Cyd	4937.8	$1.79	$8,838.62
5027031	Gap-Graded Superpave	Inside Shoulder	6	4	1.75			Ton	225.9	$48.77	$11,015.52
5020053	HMA, 4E30	Inside Shoulder	6	4	2.5			Ton	322.7	$36.77	$11,864.45
5020047	HMA, 3E30	Inside Shoulder	6	4	6			Ton	774.4	$40.40	$31,285.76
3020016	Aggregate Base, 6 inch	Inside Shoulder	6	4				Syd	2346.7	$4.29	$10,067.20
3010002	Subbase, CIP	Inside Shoulder	6	4	18			Cyd	1173.3	$4.31	$5,057.07
2050016	Excavation, Earth	Inside Shoulder	6	4	25.25			Cyd	1645.9	$1.79	$2,946.21

PROJECT COSTING ALTERNATIVE #2: JPCP PAVEMENT

REGION NO.	CONTROL SECTION	JOB NUMBER	BMP	EMP		LETTING DATE	PROJECT DESCRIPTION:
5	03033	60471	8.950	4.300		1-Dec-2006	I-196: From south of M-140 to south of
Southwest			Length =	8.900	Miles		109th Ave

PAY ITEM CODE	PAY ITEM DESCRIPTION	LANE (0=OS, 1=ML1, 2=ML2,…, 6=IS)		WIDTH (Ft)	DEPTH (Inches)	# OF RUNS or Jt SPACE (Ft)	ENTER QUANTITY	UNITS	CALC'D QUANTITY	UNIT PRICE	TOTAL COST (Per Dir. Mile)
											$578,506.81
5020032	HMA, 4C	Outside Shoulder	0	8	2			Ton	516.3	$34.33	$17,723.43
5020031	HMA, 3C	Outside Shoulder	0	8	3			Ton	774.4	$36.50	$28,265.60
5020030	HMA, 2C	Outside Shoulder	0	8	3			Ton	774.4	$34.50	$26,716.80
3037011	Open-Graded Dr Cse, 9 inch	Outside Shoulder	0	8				Syd	4693.3	$4.67	$21,917.87
3030020	Geotextile Separator	Outside Shoulder	0	8				Syd	4693.3	$0.78	$3,660.80
2050016	Excavation, Earth	Outside Shoulder	0	8	8			Cyd	1043.0	$1.79	$1,866.90
6020110	Conc Pavt, Nonreinf, 11 inch	MainLine1	1	14				Syd	8213.3	$19.19	$157,613.87
3037011	Open-Graded Dr Cse, 6 inch	MainLine1	1	14				Syd	8213.3	$3.93	$32,278.40
3030020	Geotextile Separator	MainLine1	1	14				Syd	8213.3	$0.78	$6,406.40
6020200	Joint, Contraction, Cp	MainLine1	1	14		15		Ft	4928.0	$6.30	$31,046.40
2050016	Excavation, Earth	MainLine1	1	14	8			Cyd	1825.2	$1.79	$3,267.08
6020110	Conc Pavt, Nonreinf, 11 inch	MainLine2	2	12				Syd	7040.0	$19.19	$135,097.60
3037011	Open-Graded Dr Cse, 6 inch	MainLine2	2	12				Syd	7040.0	$3.93	$27,667.20
3030020	Geotextile Separator	MainLine2	2	12				Syd	7040.0	$0.78	$5,491.20
6020200	Joint, Contraction, Cp	MainLine2	2	12		15		Ft	4224.0	$6.30	$26,611.20
2050016	Excavation, Earth	MainLine2	2	12	8			Cyd	1564.4	$1.79	$2,800.36
5020032	HMA, 4C	Inside Shoulder	6	4	2			Ton	258.1	$34.33	$8,861.72
5020031	HMA, 3C	Inside Shoulder	6	4	3			Ton	387.2	$36.50	$14,132.80
5020030	HMA, 2C	Inside Shoulder	6	4	3			Ton	387.2	$34.50	$13,358.40
3037011	Open-Graded Dr Cse, 9 inch	Inside Shoulder	6	4				Syd	2346.7	$4.67	$10,958.93
3030020	Geotextile Separator	Inside Shoulder	6	4				Syd	2346.7	$0.78	$1,830.40
2050016	Excavation, Earth	Inside Shoulder	6	4	8			Cyd	521.5	$1.79	$933.45

Alternative #1: HMA Pavement Preservation Strategy

I-196 Reconstruction

Facility: Freeway/Divided Highway
Fix Type: New/Reconstruction - Flexible HMA Pavement

Activity	Approx. Age	Cost per Lane-Mile		Number of Lanes	Present Value per Directional Mile
Maintenance	10	$33,789 $67	Agency User Cost	2	$49,898
Maintenance	13	$54,384 $67	Agency User Cost	2	$73,227
Rehabilitation or Reconstruction	26				
				Total PV=	**$123,125**

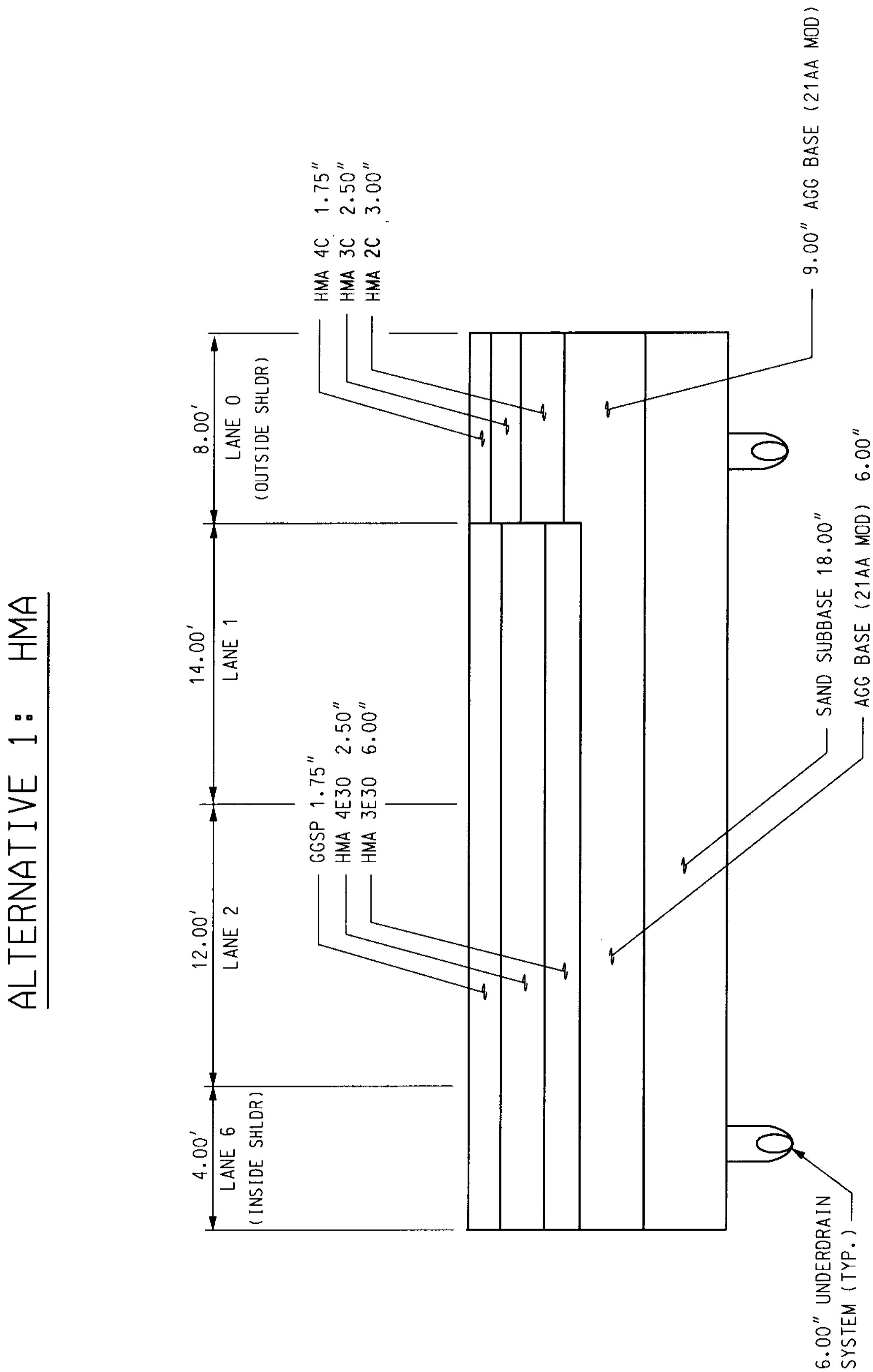
Alternative #2: JPCP Pavement Preservation Strategy

I-196 Reconstruction

Facility: Freeway/Divided Highway
Fix Type: New/Reconstruction - Rigid Concrete Pavement

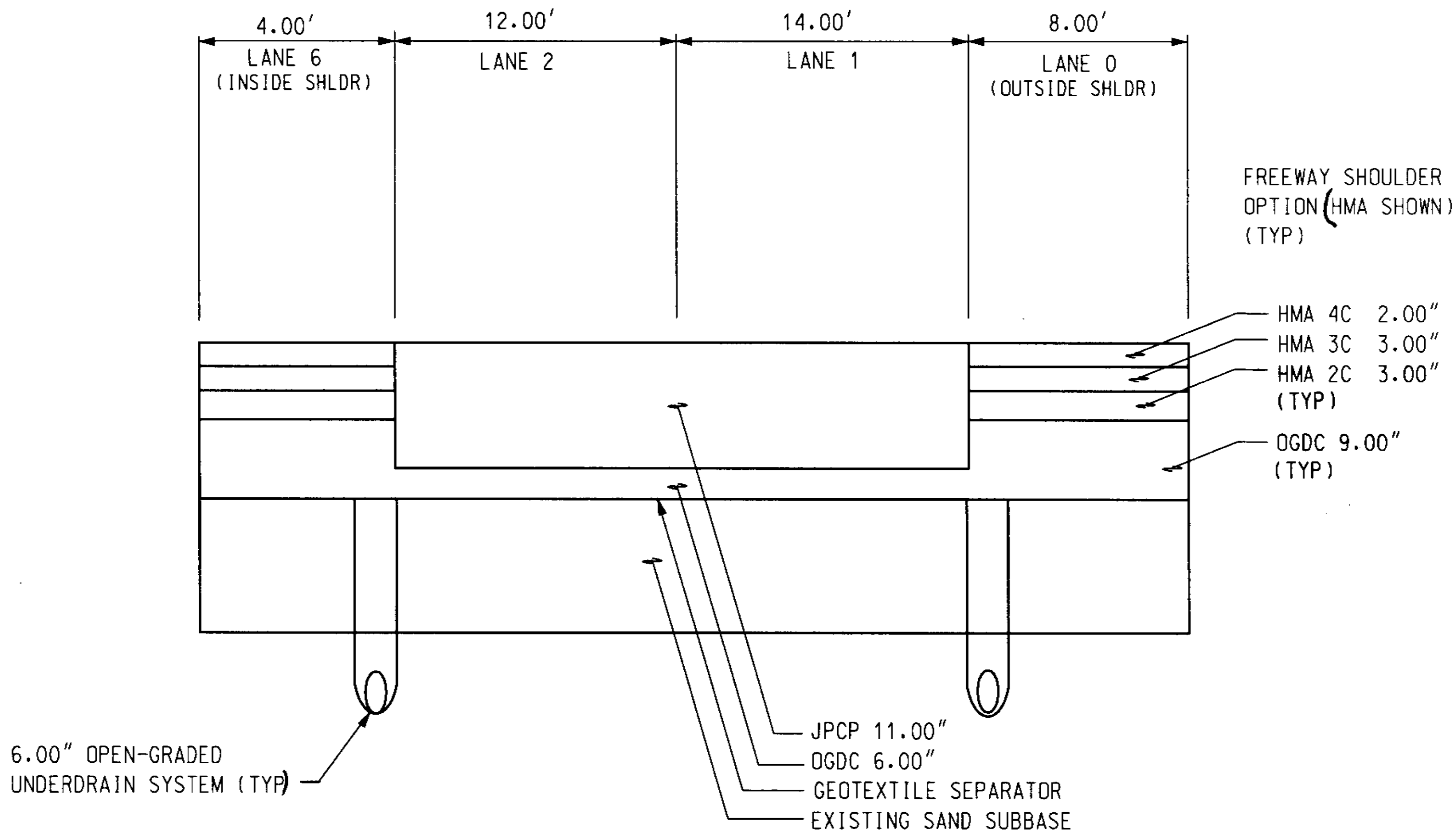
Activity	Approx. Age	Cost per Lane-Mile		Number of Lanes	Present Value per Directional Mile
Maintenance	9	$13,516 $115	Agency User Cost	2	$20,712
Maintenance	15	$41,834 $115	Agency User Cost	2	$53,073
Rehabilitation or Reconstruction	26				
				Total PV=	**$73,785**

Present Value (PV) = (Agency Maint. Cost + User Maint. Cost)/$(1+i)^n$
i = Real Discount Rate (2005: 3.1%)
n = Year of rehabilitation or reconstruction



MDOT Michigan Department of Transportation	ALTERNATE #1 HMA					
	DATE	SCALE	CONT. SEC.	JOB NO.	DESIGN UNIT	SHEET NO. R.O.W
	11/17/2004	NONE	03033	60471	JTW	5

ALTERNATIVE 2: JPCP



MDOT Michigan Department of Transportation

ALTERNATE #2 JPCP

DATE	SCALE	CONT. SEC.	JOB NO.	DESIGN UNIT	R.O.W	
11/08/2004	NONE	60471	03033			6

PROJECT COSTING ALTERNATIVE #1: HMA PAVEMENT WORKPLAN

STAGE 1	STAGE 2	STAGE 3	STAGE 4
CONST SB LANES:	CONST NB LANES:		
0	0		
1	1		
2	2		
6	6		

STAGE 1

Pay Item	Total per Dir. Mi.		Production Rate		Production Days		Project Length		Total Production Days
Excavation, Earth	15636	Cyd	2600	Cyd/day	6.0	x	8.900	Miles =	53.5
Subbase, CIP	11147	Cyd	2600	Cyd/day	4.3	x	8.900	Miles =	38.2
Aggregate Base, 6 inch	17600	Syd	6100	Syd/day	2.9	x	8.900	Miles =	25.7
Aggregate Base, 9 inch	4693	Syd	6100	Syd/day	0.8	x	8.900	Miles =	6.8
HMA, 4C	452	Ton	2000	Ton/day	0.2	x	8.900	Miles =	2.0
HMA, 3C	645	Ton	2000	Ton/day	0.3	x	8.900	Miles =	2.9
HMA, 2C	774	Ton	2000	Ton/day	0.4	x	8.900	Miles =	3.4
Gap-Graded Superpave	1694	Ton	2000	Ton/day	0.8	x	8.900	Miles =	7.5
HMA, 4E30	2420	Ton	2000	Ton/day	1.2	x	8.900	Miles =	10.8
HMA, 3E30	5808	Ton	2000	Ton/day	2.9	x	8.900	Miles =	25.8

STAGE 2

Pay Item	Total per Dir. Mi.		Production Rate		Production Days		Project Length		Total Production Days
Excavation, Earth	15636	Cyd	2600	Cyd/day	6.0	x	8.900	Miles =	53.5
Subbase, CIP	11147	Cyd	2600	Cyd/day	4.3	x	8.900	Miles =	38.2
Aggregate Base, 6 inch	17600	Syd	6100	Syd/day	2.9	x	8.900	Miles =	25.7
Aggregate Base, 9 inch	4693	Syd	6100	Syd/day	0.8	x	8.900	Miles =	6.8
HMA, 4C	452	Ton	2000	Ton/day	0.2	x	8.900	Miles =	2.0
HMA, 3C	645	Ton	2000	Ton/day	0.3	x	8.900	Miles =	2.9
HMA, 2C	774	Ton	2000	Ton/day	0.4	x	8.900	Miles =	3.4
Gap-Graded Superpave	1694	Ton	2000	Ton/day	0.8	x	8.900	Miles =	7.5
HMA, 4E30	2420	Ton	2000	Ton/day	1.2	x	8.900	Miles =	10.8
HMA, 3E30	5808	Ton	2000	Ton/day	2.9	x	8.900	Miles =	25.8

PROJECT COSTING ALTERNATIVE #2: JPCP PAVEMENT WORKPLAN

STAGE 1	STAGE 2	STAGE 3	STAGE 4
CONST SB LANES:	CONST NB LANES:		
0	0		
1	1		
2	2		
6	6		

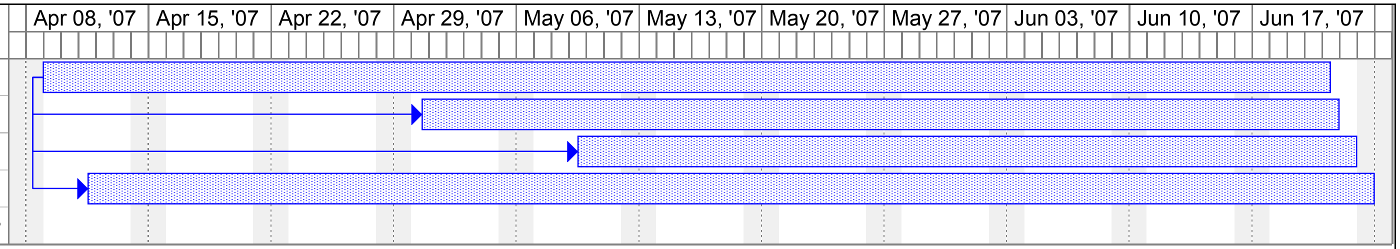
STAGE 1

Pay Item	Total per Dir. Mi.		Production Rate		Production Days		Project Length		Total Production Days
Excavation, Earth	4954	Cyd	2600	Cyd/day	1.9	x	8.900	Miles =	17.0
Geotextile Separator	22293	Syd	6100	Syd/day	3.7	x	8.900	Miles =	32.5
Open-Graded Dr Cse, 6 inch	15253	Syd	6100	Syd/day	2.5	x	8.900	Miles =	22.3
Open-Graded Dr Cse, 9 inch	7040	Syd	6100	Syd/day	1.2	x	8.900	Miles =	10.3
Conc Pavt, Nonreinf, 11 inch	15253	Syd	7200	Syd/day	2.1	x	8.900	Miles =	18.9
Joint, Contraction, Cp	9152	Ft		Ft/day		x	8.900	Miles =	3.0
HMA, 4C	774	Ton	2000	Ton/day	0.4	x	8.900	Miles =	3.4
HMA, 3C	1162	Ton	2000	Ton/day	0.6	x	8.900	Miles =	5.2
HMA, 2C	1162	Ton	2000	Ton/day	0.6	x	8.900	Miles =	5.2

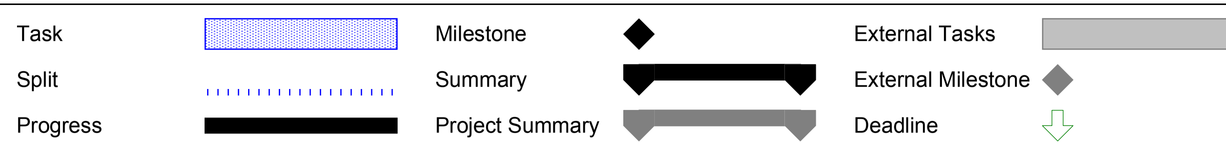
STAGE 2

Pay Item	Total per Dir. Mi.		Production Rate		Production Days		Project Length		Total Production Days
Excavation, Earth	4954	Cyd	2600	Cyd/day	1.9	x	8.900	Miles =	17.0
Geotextile Separator	22293	Syd	6100	Syd/day	3.7	x	8.900	Miles =	32.5
Open-Graded Dr Cse, 6 inch	15253	Syd	6100	Syd/day	2.5	x	8.900	Miles =	22.3
Open-Graded Dr Cse, 9 inch	7040	Syd	6100	Syd/day	1.2	x	8.900	Miles =	10.3
Conc Pavt, Nonreinf, 11 inch	15253	Syd	7200	Syd/day	2.1	x	8.900	Miles =	18.9
Joint, Contraction, Cp	9152	Ft		Ft/day		x	8.900	Miles =	3.0
HMA, 4C	774	Ton	2000	Ton/day	0.4	x	8.900	Miles =	3.4
HMA, 3C	1162	Ton	2000	Ton/day	0.6	x	8.900	Miles =	5.2
HMA, 2C	1162	Ton	2000	Ton/day	0.6	x	8.900	Miles =	5.2

ID	Task Name	Duration
1	EARTH EXCAVATION	53.5 days
2	SUBBASE	38.2 days
3	AGG BASE	32.5 days
4	HMA PAVING	52.4 days
5	**TOTAL DAYS**	**55.5 days**

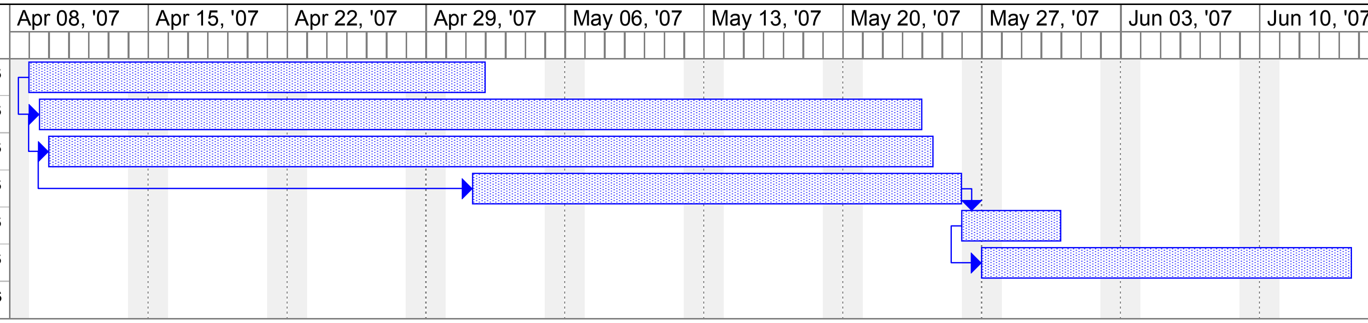


CS 03033 JN 60471
HMA STAGES 1 & 2



Alternative 1
Stages 1 & 2

ID	Task Name	Duration
1	EARTH EXCAVATION	17 days
2	GEOTEXTILE SEPARATOR	32.5 days
3	OGDC	32.6 days
4	CONCRETE PAVING	18.9 days
5	JOINTS AND CURE	3 days
6	HMA SHOULDERS	13.8 days
7	**TOTAL DAYS**	**49.4 days**



CS 03033 JN 60471
JPCP STAGES 1 & 2

Task | Milestone | External Tasks
Split | Summary | External Milestone
Progress | Project Summary | Deadline

Alternative 2
Stages 1 & 2

MDOT Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: July 21, 2004

TO: Kyle Rudlaff

FROM: Amy Lipset, Project Planning

SUBJECT: TAR #1252: I-196, CS 80012, 80013, & 03033, JN 60471C

Traffic Information

The following table contains the requested traffic information for I-196 from M-140 to south of 109th Avenue (CS 80012, MP 8.950 – CS 03033, MP 4.300) in Van Buren and Allegan Counties. Current traffic volumes were calculated from hose counts taken in 2000. A growth rate of 1.5 % was used to calculate future traffic volume. This number is based on past growth, regression analysis and population projections in the counties.

	2007	2027
Total Average Daily Traffic (ADT)	22,300	30,000
Directional ADT	11,150	15,000
% Commercial of ADT	30 %	30 %
Total Commercial of ADT	6,700	9,000

	Rigid	Flexible
Growth Rate	1.5 %	1.5 %
Growth Type	Compound	Compound
Initial Yearly 18-kip ESAL (both directions)	2,372,140	1,760,760
Direction Distribution Factor	50 %	50 %
Lane Distribution Factor	81 %	81 %
Total 18 Kip Axle Loadings	22,215,290	16,489,670

The DHV is 12 %. If you have any questions regarding this traffic analysis please contact me at 517.373.2909.

MDOT Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: July 10, 2004

TO: Patricia Schafer
Pavement Management Engineer, Technical Services

FROM: Bobbi Welke
Southwest Region Engineer

SUBJECT: Maintaining traffic scheme for the life cycle cost analysis and pavement selection for CS 80013, JN 60471: 8.9 miles of rehabilitation on northbound and southbound I-196 from abandoned railroad bridge, 0.7 miles south of M-140 to south of 109th Avenue interchange; South Haven Township in Van Buren County and Casco Township in Allegan County.

This project meets the $1 million paving cost threshold for life cycle cost analysis. In accordance with the pavement selection procedures, this memo outlines our intended scheme for maintaining traffic. The following restrictions and staging will apply to all rehabilitation alternatives under consideration. Due to the high traffic volumes on I-196, traffic will utilize a crossover regardless of the fix chosen.

1. **Traffic Restrictions:**
   This will be a two-year project. A minimum of one lane of traffic in each direction must be maintained at all times through out the project limits during the construction season. All ramps must be maintained at all times using temporary ramps or detoured to other interchange ramps. No work affecting the part width construction or hauling in the open lanes will be permitted during holiday periods.

   Due to the high traffic volumes, it is desirable to maintain a speed limit of sixty miles per hour on I-196 in order to prevent unnecessary delay to the motorists. Construction vehicles will not be allowed to enter open traffic lanes when entering or exiting the work site as this will cause unnecessary delays to the motoring public.

2. **Proposed Staging:**
   I-196 is a four lane limited access freeway. One lane of traffic in each direction, separated by temporary concrete barrier, will be maintained on the northbound side of the median while southbound I-196 is being constructed. Temporary crossovers will be used to get traffic across the median at each end of the project and at the M-140 and Phoenix Road interchange ramps. The interchange ramps at North Shore Drive (Exit 22) will be closed for the duration of the project and detoured utilizing Blue Star Highway to the Phoenix Road interchange.

Stage 1: Rebuild shoulders for maintenance of traffic on northbound I-196. Build crossovers and temporary ramp connectors at M-140 and Phoenix Road interchanges. Work to be completed in first year of project.

Stage 2: Perform structure work on Phoenix Road and Deer Lick Creek bridges. Build temporary ramp connectors at M-140 and Phoenix Road interchanges. Work to be completed in first year of project.

Stage 3: Maintain one lane of traffic in each direction along northbound I-196 by crossing southbound traffic over the median at the POB and POE. Complete road and bridgework along southbound I-196 between POE and POE. Work to be completed in first year of project.

Stage 4: Maintain one lane of traffic in each direction along southbound I-196 by crossing northbound traffic over the median at the POB and POE. Complete road and bridgework along northbound I-196 between POE and POE. Work to be completed in second year of project.

The total cost for maintaining traffic is estimated to be approximately $3.0 million regardless of the fix.

If you have further questions, please contact Sarah Woolcock, Development Engineer, Coloma Transportation Service Center at (269) 849-1184, extension 346.

Southwest Region Engineer

RSW/GL/lh

cc: P. South
S. Woolcock
L. Ramos
G. Loyola
M. Jones
J. Klee
K. Rothwell
D. Gauthier
B. Pena
J. Early

USER COST SUMMARY

NB:	Weekday	$9,309	Weekend	$12,224
SB:	Weekday	$9,309	Weekend	$12,224

Alternative #1: Flexible HMA Pavement

Stage 1 = 55.5 days

NB:	Weekdays:	40 days @	$9,309	per day =	$372,351
	Weekends:	16 days @	$12,224	per day =	$195,590
SB:	Weekdays:	40 days @	$9,309	per day =	$372,351
	Weekends:	16 days @	$12,224	per day =	$195,590

Stage 2 = 55.5 days

NB:	Weekdays:	40 days @	$9,309	per day =	$372,351
	Weekends:	16 days @	$12,224	per day =	$195,590
SB:	Weekdays:	40 days @	$9,309	per day =	$372,351
	Weekends:	16 days @	$12,224	per day =	$195,590
				Total =	$2,271,766

Total Initial User Cost = $2,271,766 / (2 * 8.9 dir-mile) = **$127,627 /dir-mile**

Alternative #2: Rigid JPCP Pavement

Stage 1 = 49.4 days

NB:	Weekdays:	36 days @	$9,309	per day =	$335,116
	Weekends:	14 days @	$12,224	per day =	$171,142
SB:	Weekdays:	36 days @	$9,309	per day =	$335,116
	Weekends:	14 days @	$12,224	per day =	$171,142

Stage 2 = 49.4 days

NB:	Weekdays:	36 days @	$9,309	per day =	$335,116
	Weekends:	14 days @	$12,224	per day =	$171,142
SB:	Weekdays:	36 days @	$9,309	per day =	$335,116
	Weekends:	14 days @	$12,224	per day =	$171,142
				Total =	$2,025,031

Total Initial User Cost = $2,025,031 / (2 * 8.9 dir-mile) = **$113,766 /dir-mile**

SummaryView

period length (min)	0	
annual traffic growth (%)	1.50%	
years of growth		
VEHICLE INPUT	cars	trucks
design demand (%)	70.0%	30.0%
user cost per hour ($/V hr)	$14.35	$25.32
user cost per mile, ($/V mi)	$0.405	$1.18
user cost per cancellation, ($/V)		

PROJECT INFORMATION	
PROJECT TITLE	I-196 from south of M-140 to south of 109th Avenue
C.S.	03033
JOB #	60471
START DATE	

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT SUMMARY SHEET
DIVISION	C&T
REPORT BY	BK
REPORT DATE	02/18/2005

NOTES: Traffic will be maintained using temporary crossovers. One bound will be reconstructed at a time.

METHOD INPUT		On Northbound		On Southbound					
	method title								
DISTANCE AND SPEED	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	10.4	see delay	10.4	see delay		see delay		see delay
	normal travel	10.4	70.0	10.4	70.0				
diversion	method travel								
	normal travel								
SPEED DELAY		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/period)		1395		1395					
speed (when D~0) (mph)		60		60					
speed (when D=C) (mph)		37		37					
DECREASE TO DEMAND		threshold	range	threshold	range	threshold	range	threshold	range
capacity for decreases to design demand (V/period)									
canceled cars (with no delay) (%)									
canceled trucks (with no delay) (%)									
canceled cars (with delay) (%/min)									
canceled trucks (with delay) (%/min)									
diverted cars (with no delay) (%)									
diverted trucks (with no delay) (%)									
diverted cars (with delay) (%/min)									
diverted trucks (with delay) (%/min)									
OTHER USER COST INPUT		cars	trucks	cars	trucks	cars	trucks	cars	trucks
other user cost per actual demand ($/V)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
user cost per diversion ($/V)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

PERIOD INPUT			backup at start (V)		0	0	0	0	0	0	0	0
	weekday	weekend	weekday	weekend	weekday	weekend	weekday	weekend	weekday	weekend	weekday	weekend
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	129	401	129	401	1395	1395	1395	1395				
1 A	79	411	79	411	1395	1395	1395	1395				
2 A	70	391	70	391	1395	1395	1395	1395				
3 A	68	397	68	397	1395	1395	1395	1395				
4 A	106	328	106	328	1395	1395	1395	1395				
5 A	218	319	218	319	1395	1395	1395	1395				
6 A	383	568	383	568	1395	1395	1395	1395				
7 A	537	663	537	663	1395	1395	1395	1395				
8 A	528	690	528	690	1395	1395	1395	1395				
9 A	557	742	557	742	1395	1395	1395	1395				
10 A	614	709	614	709	1395	1395	1395	1395				
11 A	653	732	653	732	1395	1395	1395	1395				
12 P	674	674	674	674	1395	1395	1395	1395				
1 P	717	717	717	717	1395	1395	1395	1395				
2 P	786	786	786	786	1395	1395	1395	1395				
3 P	839	839	839	839	1395	1395	1395	1395				
4 P	843	843	843	843	1395	1395	1395	1395				
5 P	825	825	825	825	1395	1395	1395	1395				
6 P	664	664	664	664	1395	1395	1395	1395				
7 P	533	533	533	533	1395	1395	1395	1395				
8 P	437	453	437	453	1395	1395	1395	1395				
9 P	358	502	358	502	1395	1395	1395	1395				
10 P	268	539	268	539	1395	1395	1395	1395				
11 P	202	506	202	506	1395	1395	1395	1395				
Total	11089.286	14234.201	11089	14234	33480	33480	33480	33480	0	0	0	0

SUMMARY OUTPUT								
traffic method								
direction	weekday	weekend	weekday	weekend	weekday	weekend	weekday	weekend
total user cost	$9,309	$12,224	$9,309	$12,224				
user cost of delays	$9,309	$12,224	$9,309	$12,224				
user cost of decreases	$0	$0	$0	$0				
maximum backup (V)	0	0	0	0				
maximum backup length (lane mi)	0.0	0.0	0.0	0.0				
maximum delay (min.)	3.8	3.8	3.8	3.8				
average delay, except diversions (min)	2.9	2.9	2.9	2.9				
total delay, except diversions (V hr)	528	693	528	693				
total vehicles canceled(V)	0	0	0	0				
total vehicles diverted (V)	0	0	0	0				
total decrease in demand (V)	0	0	0	0				
% decrease in demand	0.0%	0.0%	0.0%	0.0%				
delay per diverted vehicle (min)	0.0	0.0	0.0	0.0				
total diversion delay (V hr)	0	0	0	0				
average delay, including diversions (min)	2.9	2.9	2.9	2.9				
total delay, including diversions (V hr)	528	693	528	693				
user cost / design demand	$0.84	$0.86	$0.84	$0.86				
delay cost / actual demand	$0.84	$0.86	$0.84	$0.86				
Aut(ON Prin(ON No(OK validity of output	VALID	VALID	VALID	VALID	NOT VALID	NOT VALID	NOT VALID	NOT VALID

TABLE A
User Costs for Maintenance Activities

Total ADT	Facility	User $/day	Day/ln-mile		Day/ln-mile	Bituminous	Concrete
			Bit		Concrete	User $/ln-mile	User $/ln-mile
0 to 40,000	Fwy.*	$191	0.35		0.6	$67	$115
40,001 to 80,000	Fwy.*	$321	0.35		0.6	$112	$193
80,001 to 120,000	Fwy.*	$658	0.35		0.6	$230	$395
0 to 40,000	Divided Hwy.*	$288	0.35		0.6	$101	$173
40,001 to 80,000	Divided Hwy.*	$489	0.35		0.6	$171	$293
80,001 to 120,000	Divided Hwy.*	$909	0.35		0.6	$318	$545

* User costs based on a one lane closure.

<u>Computations:</u>

Maintenance for HMA

1 lane-mile @ 165 lbs/syd (12 ft/lane)
Production = 1650 Ton/day
(165 lbs/syd x 12 ft/ln x 5280 ft/mile x syd/9 sft)/(2000 lbs/Ton) = 581 Ton/ln-mile
(581 Ton/ln-mile)/1650 Ton/day = 0.35 day/ln-mile

Maintenance for Concrete

1 lane-mile @ 30 patches/ln-mile
Production = 50 patches/day
(30 patches/ln-mile)/(50 patches/day) = 0.6 day/ln-mile

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Michigan Department Of Transportation
8885 Ricks Rd
Lansing, MI
United States of America

Flexible Structural Design Module

CS 03033, JN 60471 HMA pavement

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	16,489,670
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,150 psi
Stage Construction	1
Calculated Design Structural Number	6.52 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Gap Graded Superpave Top Course	0.42	1	1.75	-	0.73
2	4E30 Leveling Course	0.42	1	2.5	-	1.05
3	3E30 Base Course	0.36	1	6	-	2.16
4	Agg. Base	0.14	1	6	-	0.84
5	Sand Subbase	0.1	1	18	-	1.80
Total	-	-	-	34.25	-	6.59

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Michigan Department Of Transportation
8885 Ricks Rd
Lansing, MI
United States of America

Rigid Structural Design Module

CD 03033, JN 60471 Concrete pavement

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	22,215,290
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	670 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	180 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.7
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	10.88 in

MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: August 10, 2004

TO: Mike Eacker, Pavement Management Unit
Lansing C&T Support Area

FROM: Jack A. Klee, Region Soils Engineer
Southwest Region

SUBJECT: CS 80013/03033 - JN 60471C, I-196, from 0.7 miles south of M-140, northerly 8.9 miles to 0.2 miles south of 109th Avenue, Van Buren and Allegan County(s)
Typical Soils, Recommended Resilient Modulus (M_r)

The project limits are from 0.7 miles south of M-140, northerly 8.9 miles to 0.2 miles south of 109th Avenue, in Van Buren and Allegan County(s).

The existing roadway is a 24 foot wide, 9 inch reinforced concrete pavement, with HMA shoulders.

The recommended Resilient Modulus (M_r) for this project, is **4,150 psi.** This recommendation is based on an examination of the soil borings from the area, and past projects on this roadway, and the surface geology of the area.

Based on the soil borings, and a review of the USDA, Soil Conservation Service, Soil Survey Map(s) for Van Buren and Allegan County(s), the typical soil series for the project range from the poorly drained Waldenberg (loamy sand) series and somewhat poorly drained Selfridge (loamy sand) series for the southern portion (south of the Black River) to the imperfectly drained Rimer (fine sand to fine loamy sand) and Conover (fine sandy loam to silty loam) series.

I recommend a geo-textile separator layer be used. Sampling and review of the existing subbase has found that it is acceptable for use under the current MDOT specifications [Section(s) 301, 902; 2003 Standard Specifications for Construction].

If you have any questions, you may contact me at the Southwest Region Office, 269-337-3952.

Region Soils Engineer

cc: Sarah Woolcock, Coloma TSC
Kyle Rudlaff, Coloma TSC

CS 03033, JN 60471

K = 285 pci

K_LS = 180 pci

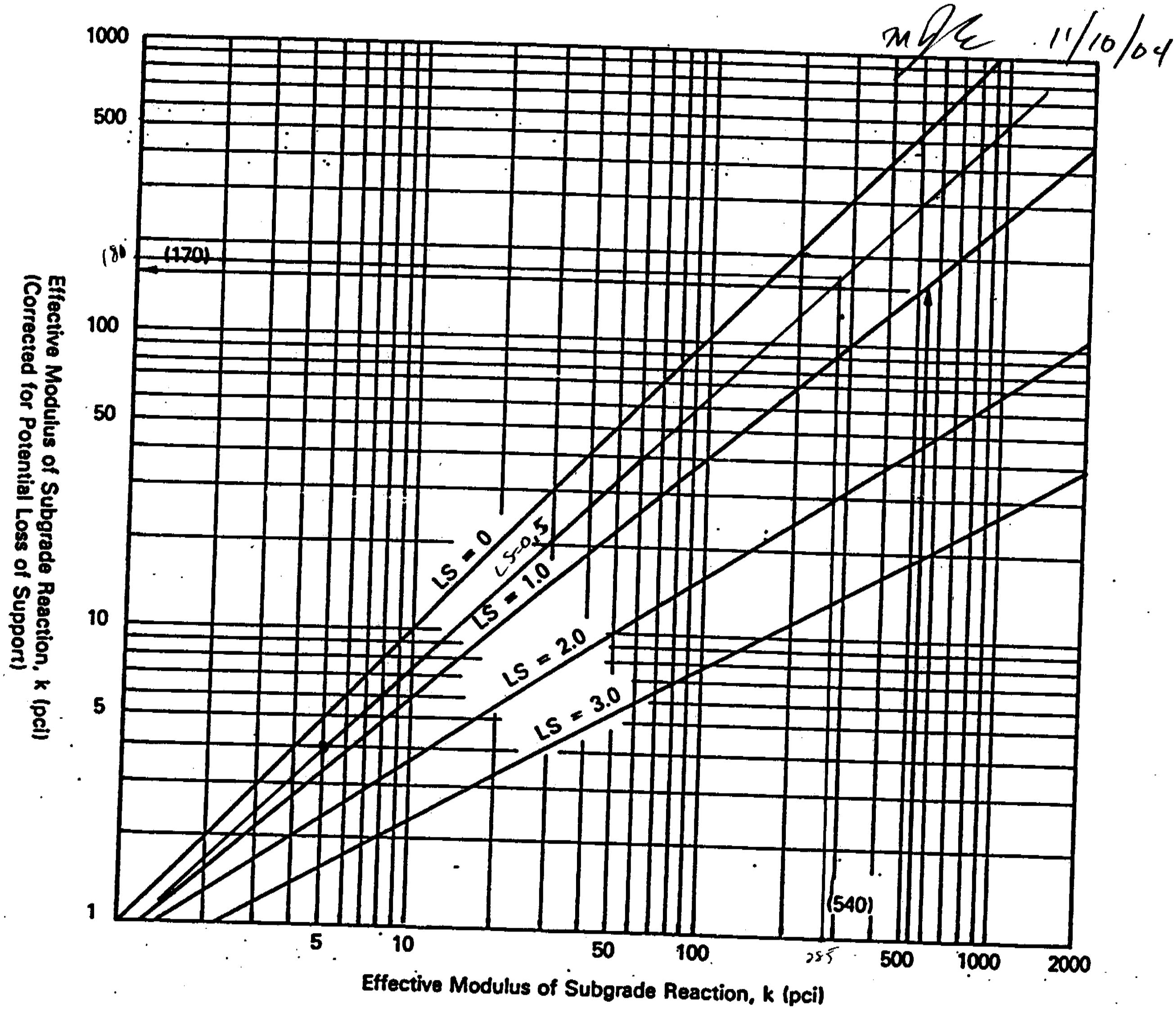


Figure 3.6. Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support (6)

CS 03033, JN 60471

M_R = 4150 psi

E = 13,500 psi

D = 14"

k = 285 pci

Example:

D_{SB} = 6 inches

E_{SB} = 20,000 psi

M_R = 7,000 psi

Solution: k_∞ = 400 pci

mJE 11/10/04

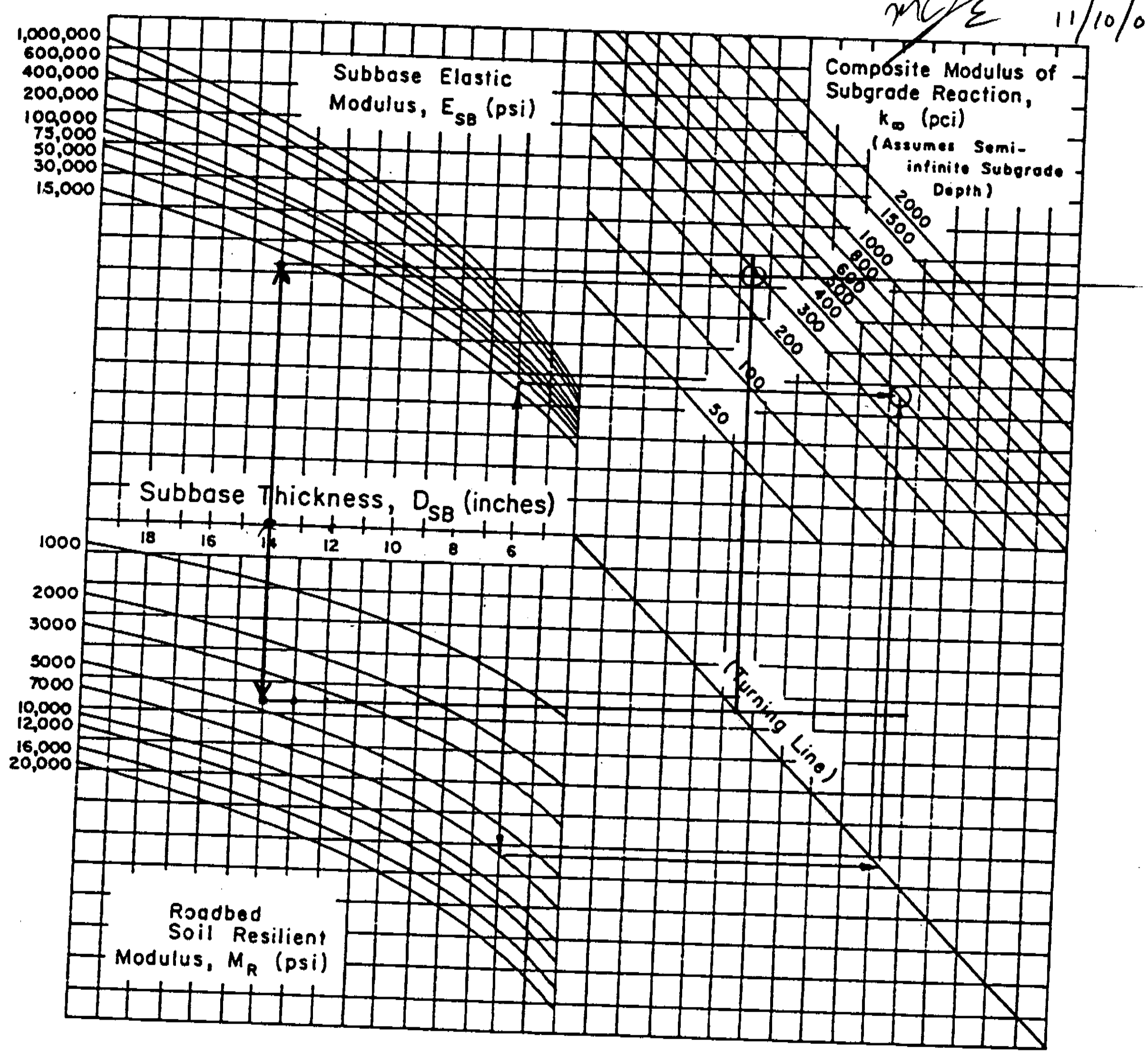


Figure 3.3. Chart for Estimating Composite Modulus of Subgrade Reaction, k_∞, Assuming a Semi-Infinite Subgrade Depth. (For practical purposes, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)